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U.S. Department of Transportation
National Highway Traffic Safety Administration

Memorandum

89-20-N03-001

Subject: ACTION: Docket Submittal Re: FMVSS No. 207, Seating Systems; Docket No. 89-20, Notice 3

Date: OCT 8 1992

From: William J. J. Liu, Ph.D.
Safety Standards Engineer (NRM-12)

Reply to Attn of

ORIGINAL

To: Docket Section

Via: Patricia Breslin, Director
Office of Vehicle Safety Standards

Via: Paul Jackson Rice
Chief Counsel

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Total of three reports only 94 pg.

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The attached documents should be placed in the above docket at the time of the publication of a Request for Comments notice in the Federal Resister on this subject.

- "Summary of Safety Issues Related to FMVSS No. 207, Seating Systems," Prepared by the National Highway Traffic Safety Administration, September 1992. (40 pgs)

- "Seat Damage and Occupant Injury in Passenger Car Towaway Crashes," Susan C. Partyka, Office of Vehicle Safety Standards, National Highway Traffic Safety Administration, June 8, 1992. (48 pgs)

- "Research Plan for Seating Systems," Prepared by the National Highway Traffic Safety Administration, September 1992. (5 pgs)

- "Upgrade Seating - Patents, Literature Search, and Accident Analysis," Kennerly Digges and John Morris, University of Virginia, Prepared for the National Highway Traffic Safety Administration, September 1, 1992. (174 pgs)

4 Attachments (10 copies)

NOTE: THIS DOCUMENT, "UPGRADE SEATING - PATENTS, LITERATURE SEARCH, AND ACCIDENT ANALYSIS," WILL BE AVAILABLE IN THE TECHNICAL REFERENCE LIBRARY IN ROOM 5110 FOR VIEWING ONLY. ALSO IT WILL BE AVAILABLE FROM THE NATIONAL TECHNICAL INFORMATION SERVICE (NTIS) IN SPRINGFIELD, VA. 22161.

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SUMMARY OF SAFETY ISSUES RELATED TO FMVSS NO. 207, SEATING SYSTEMS

Prepared by:
The National Highway Traffic Safety Administration
September 1992

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Summary of Safety Issues Related To FMVSS No. 207, Seating Systems

I. INTRODUCTION

The purpose of this report is to summarize recent work on the safety issues related to the Federal Motor Vehicle Safety Standard (FMVSS) No. 207, "Seating Systems." This technical report has been prepared in support of the notice published in the Federal Register by the National Highway Traffic Safety Administration (NHTSA) concerning FMVSS No. 207. This report first reviews the background and requirements of the present standard, identifies seating system performance issues fur safety goals, summarizes current NHTSA evaluations, research, and laboratory testing, and finally reviews the technical literature on seating system safety.

II. FMVSS NO. 207, SEATING SYSTEMS

A. The Current Standard

Federal Motor Vehicle Safety Standard (FMVSS) No. 207, "Seating Systems," first went into effect on January 1, 1968, for passenger cars only. The 1968 standard was basically adopted from the requirement of the Society of Automotive Engineers Recommended Practice J879, "Passenger Car Front Seat and Seat Adjuster," November 1963.

On January 1, 1972, the standard was extended to multipurpose passenger vehicles, trucks, and buses. The amended FMVSS No. 207, "Seating Systems,@@ adopted the test procedures in the revised SAE 5879. The SAE 5879 was revised in July 1968 and was renamed "Motor Vehicle Seating Systems - SAE J879b."

On March 19, 1974, NHTSA proposed a modification of FMVSS No. 207, but the rulemaking action was terminated in 1978. Consequently, the standard has not been upgraded since January 1, 1972.

B. Recent Petitions to Upgrade the Standard

On March 3, 1988, Edward J. Hurkey petitioned NHTSA to look into the "slingshot" effect on restrained occupants during rear impacts and to amend the requirements for safety belt retractors in FMVSS No. 208, "Occupant Crash Protection," and FMVSS No. 209, "Seat Belt Assemblies." The "slingshot" effect is a rebound effect whereby an occupant is propelled forward from a deformed seat due to the recovery of elastic energy. The petitioner believed that the emergency lock retractor (ELR) on some safety belts unlocked during the occupant's rebounding and therefore could not prevent the "slingshot" effect during an impact. On July 24, 1989, NHTSA notified Mr. Horkey that his petition was granted. The petition was entered into NHTSA's Docket No. 89-20-N01-001.

On April 18, 1989,Kenneth J. Saczalski petitioned NHTSA to reexamine the general performance requirements of FMVSS No. 207. In particular, the petitioner suggested upgrading the seat back requirements for rear impacts. On July 24, 1989, NHTSA notified Dr. Saczalski that his petition was granted. The petition was also entered into NHTSA's Docket No. 89-20-N01-001 and Docket No. PRM-207-001.

On October 4, 1989, NHTSA published a Request for Comments notice and sought comments on the Horkey and Saczalski petitions. Based on responses to the notice (Docket No. 89-20-N01) and agency review and analysis, on October 17, 1990, NHTSA published a Termination of Rulemaking notice on the Horkey petition. The termination notice stated that NHTSA was unable to establish that amending the requirements for safety belt retractors would provide any significant safety benefits.

On December 28, 1989, Alan Cantor petitioned NHTSA to amend FMVSS No. 207 to eliminate "ramping" along a collapsed seat back during rear impacts. "Ramping" is movement of an occupant rearward and upward along the seat back during a rear impact. On February 28, 1990, NHTSA notified Mr. Cantor that his petition was granted. The petition was entered into NHTSA's Docket No. PRM-207-002.

C. Test Requirements of the Current Standard

Test requirements of the current FMVSS No. 207 are summarized in the following paragraphs.

Each occupant seat, other than a side-facing seat or a passenger seat on a bus shall "withstand" the applied forces.

- Force: A force equal to 20 times the weight of the seat is applied through the center of gravity (c.g.) of the seat in a forward and in a rearward longitudinal direction. If a seat belt assembly is attached to the seat, an additional force (FMVSS No. 210, "Seat Belt Assembly Anchorages," S4.2's requirement) is applied to the forward direction only for forward-facing seats and rearward only for rearward-facing seats.

- Moment: A force that produces a 3,300 inch-pound moment about the seating reference point is applied to the seat back for each designated seating position that the seat provides. The force is applied to the rearward direction only for forward-facing seats and forward only for rearward-facing seats.

- Seat back lock or seat back restraint device: For a forward-facing seat, a forward longitudinal force equal to 20 times the weight of the seat back is applied through the c.g. of the seat back. Similarly, for a rearward-facing seat, a rearward force equal to 8 times the weight of the seat back is applied. In addition, the restraining device is required to **"not release"** when it is subjected to an acceleration of 20g in the direction opposite to that in which the seat folds.

D. Comparison of U.S. and Foreign Seating System Safety' Requirements

The following table shows a comparison of test requirements on seating systems between the U.S. and some other countries. Note that the test requirements are essentially the same except that the ECE Regulation #17 requires a higher test moment (4,690 in-lb vs. 3,300 in-lb).

Comparison of U.S. and Other Country's Seating Systems Test Requirements

Country	Test Force on Seating System C.G. of Seat	Test Moment on Seating Reference Pt. (Per Seat Occupant)	Test Force on Seat Back Lock C.G.-Seat Back
U.S.A.	20g	3,300 in-lb	20g
Canada	20g	3,300 in-lb	20g
ECE Reg. #17 Rev. 3	20g	4,690 in-lb (53 daNm)	20g
Japan	20g	3,300 in-lb (Approx.) (38 Kg-m)	20g
Sweden	20g	3,300 in-lb (Approx.) (38 Kg-m)	20g
Brazil	20g	3,300 in-lb	20g
Australia	20g	3,300 in-lb	20g

XII. ANALYSES OF SAFETY PROBLEM

A. Seating System Performance Issues

Based on the Saczalski and Cantor petitions, the comments submitted in response to the October 4, 1989 notice, and agency research, the agency has determined that there are four categories of performance issues which need to be addressed as part of the consideration of any upgrade of Standard No. 207.

The first category is seating system integrity. Seating system integrity refers to the ability of the seat and its anchorage to the vehicle to withstand crash forces without failure. Examples of failure of the seating system would include: breakage of the seat adjusters, breakage of the folding seatback locks and supports, or separation of the anchorage from the vehicle.

The second category is the energy absorbing capability of a seat. The energy absorbing capability of a seat includes the manner in which the seat and its attachment components absorb energy, and the manner in which the seat and its attachment components release energy.

The third category is compatibility of a seat and its head restraint. The concern in this category is that any change in seat back energy absorbing capability could exacerbate head or neck injuries if the geometry and energy absorbing capability of the head restraint is not also changed.

The fourth category is the safety belt restraint system. A seating system and its safety belt restraint system must complement each other to prevent injury. Several manufacturers are considering integrated seats, i.e., seats which have the safety belt attached to their seat structure to increase the compatibility of these systems.

B. Seating System Safety Concerns

Most of the concerns raised in the rulemaking petitions, in comments submitted in response to the October 4, 1989 Request for Comments, and in the literature relate to the energy absorbing characteristics of the seating system. Specifically, they concern how to achieve a proper "balance" in stiffness. Concern has been expressed by commenters and in the literature that if a seating system is too stiff, injuries could be increased in a rear impact collision because of the exacerbation of several problems: occupant rebound off the seat back into the frontal components, ramping of the occupant into the roof of the vehicle, direct contact with the seat back, and phasing problems between the neck/back body regions contacting the head restraint and the seat back. On the other hand, concern has been expressed that if the seating system appears to bend too far backward when the vehicle is struck in the rear, injuries to front seat occupants could be increased by the exacerbation of several other problems: ramping toward the rear components, contact with the rear seat and/or rear seat occupants, and loss of vehicle control.

Further, there could be an increase in injuries fur rear seat occupants also.

In an attempt to define the proper "balance" related to this energy absorbing or stiffness characteristic plus a better understanding of the other issues discussed above, a number of efforts have been undertaken. The first effort was to publish a notice of Request fur Comments in the Federal Register requesting comments on the subject petitions and information on seat back performance characteristics. Partial results of this effort were published in another notice, a Termination of Rulemaking, in the Federal Register and are discussed further in subsequent sections of this report.

The remaining part of this section is concentrated on seating system related data analysis and review. Analyses were undertaken of NHTSA accident data files including both an exploratory data analysis and a hard copy investigation of selected cases. A review of NHTSA tested seating system performance data was conducted including FMVSS No. 207 and FMVSS No. 301 rear impact tests, and New Car Assessment Program (NCAP) rear and frontal impact tests. Also, the agency's recent defect investigation files related to this subject were examined.

C. Accident Data

1. National Accident Sampling System - Exploratory Analysis of Computerized Database

The 1988 to 1990 National Accident Sampling System (NASS) data describe seat type and seat performance for occupants of light passenger vehicles that were towed from the scene because of damage received in the crash. NASS also collects data describing the crash circumstances, vehicle damage, occupant factors, and resulting injuries. The NASS sites were randomly selected to represent the national accident experience and cases were selected randomly in each site, so the weighted NASS data produce national estimates of light vehicle tuwaway accidents. The complete analysis of the NASS data is presented in a detailed report, "Seat Damage and Occupant Injury in Passenger Car Towaway Crashes," Susan C. Partyka, Office of Vehicle Safety Standards, Rulemaking, National Highway Traffic Safety Administration, June 8, 1992. This report can be found in NHTSA's Docket No. 89-20-N03.

In interpreting the results, the report states that "[t]his report describes an exploratory data analysis of seat damage and occupant injury performed to provide insight into injury mechanisms, to suggest questions for further research, and to help establish the safety priority of these questions. Occupant involvements and injuries were estimated from a statistical survey of towaway crashes, and these estimates are subject to sampling and nonsampling error. Estimates of sampling variability are beyond the scope of the present effort, and no claims of statistical significance are implied by the comparisons made here."

Ten percent of occupied front-outboard passenger car seats (the *driver* and right-front seats) were deformed *(by* occupant contact or intrusion) or their hardware was damaged in the crash (the seat adjusters, folding locks, tracks, or anchors were broken).

While most of the interest related to seating system performance has been focused on rear impacts, it should be stressed that seat *damage* occurs in all crash modes. Rear impacts account for a third of seat damage, and seat damage was much more common in rear impacts than in other towaway impact types. In recent towaway crashes,

38 percent of seats in rear impacts were damaged,
19 percent of seats in near-side impacts were damaged,
9 percent of seats in rollover crashes were damaged,
7 percent of seats in far-side impacts were damaged, and
5 percent of seats in frontal impacts were damaged.

The type of seating system damage differed among the different crash modes. Deformation from occupant loading (which relates to the energy absorption issue) accounts for 71 percent of the damage types in rear impacts. The seat damage in frontal impacts and rollover crashes relate about equally to broken hardware (which relates to the structural integrity issue) and occupant loading. For side impacts, seat damage primarily relates to deformation from vehicle intrusion, which is not being considered within this effort. It appears that damage in frontal crashes is associated with more severe crashes compared to that seen in rear impacts. For crashes with known severity as measured by delta-v, 41% of the seats damaged in frontal impacts occur with a delta-v of at least 20 mph, while in rear impacts, 24% occur with a delta-v of at least 20 mph. The energy absorption concern appears to be more an issue in rear impacts, where the indication of structural integrity problems appears to be much less than those associated with occupant loading.

In examining the accident data for information linking the performance of seating systems with injury causation it was found that occupants in damaged seats tended to be injured more severely than occupants in undamaged seats, largely because seat damage indicated a high-severity crash. Thus, in order to further explore the relationship between seat damage and injury, several methods were utilized to control for crash severity. These methods are fully discussed in the detailed paper on this analysis as presented in the previously referenced report.

Overall the results were unclear and did not consistently show a pattern of increased likelihood of injury fur damaged seats.

For the injury rate comparisons that were made within ranges of crash severity, in frontal crashes, occupants of damaged seats had higher injury rates than did those in undamaged seats fur each 10 mph range of delta-v. It is not clear from these data whether stronger seats would have prevented injury, because crashes in which seats are damaged may differ in important ways from those in which seats are nut damaged, even within a range of crash severities. It also should be stressed that the type of damage in frontal crashes are mixed -- the damage types consists of what was defined earlier as structural integrity and energy absorption characteristics. Also, it should be repeated that only a small percentage of seats sustain damage in frontal impacts. In any case, there dues appear to be some indication that the likelihood of injury to occupants is greater fur damaged seats.

Fur rear impact crashes, the data are very limited after -controlling for crash severity. However, the results are mixed, with occupants of damaged seats having higher injury rates than those in undamaged seats in the lower delta-v ranges, while in the higher delta-v ranges the occupants of undamaged seats had higher injury rates. Fur rear impacts this damage was primarily related to the energy absorption characteristic.

The previously referenced report examines many other variables related to seat damage that would need to be controlled for in isolating the effect of seat damage on injury causation. For example, the analysis concluded that the likelihood of seat damage increases with increasing occupant weight and increasing age of the vehicle. Also, belt use rates were higher in undamaged seats, possibly because belt users tended to be involved in less severe crashes, or because belt use reduces occupant loading of the seat.

The exploratory NASS analysis also examined any similarities and/or differences in injury patterns for occupants of damaged and undamaged seats. The analysis found that unbelted occupants of damaged seats in rollover, frontal impacts, and side impacts were more likely to be ejected than were unbelted occupants of undamaged seats. In large part, the differences in ejection rates reflect differences in crash severity -- severe crashes were more likely to result in seat damage and to involve occupant ejection and injury. There are very few ejections from cars with damage to the rear, but the available data do nut suggest that occupants in damaged seats were more likely to be ejected than were occupants in undamaged seats.

As to the distribution of body regions injured and the source of these injuries, the previously referenced report presents the results of this analysis for all crash modes. In this summary, specific attention is focused on rear crashes. For these impacts, the head/neck area generally accounted for 42% of the moderate or greater injuries (AIS 2+), while the torso accounted for 57% of serious and more severe injuries (AIS 3+). Seat backs were cited as the source of moderate and more severe injury in a high percentage of cases:

13 percent for those unbelted in undamaged seats,
6 percent for those belted in undamaged seats,
26 percent for those unbelted in damaged seats, and
24 percent for those belted in damaged seats.

Occupants of seats damaged in rear impacts receive more of their injuries from seat back contact than did occupants in rear impacts with undamaged seats. This may reflect, in part, the severity of the crash that resulted in heavy occupant loading of the seat back.

For occupants with damaged and undamaged seats in rear impacts, a high percentage -- approximately 70% for undamaged seat injury sources and approximately 30% for damaged seat injury sources -- of the injuries were attributed to passenger compartment front components; this suggests that the occupant may have rebounded from the seat, forward, or contacted frontal components as the seat back rotated backward, or contacted the frontal components in a subsequent frontal impact.

There were very few moderate and more severe injuries attributed to a contact that could be determined to have been made behind a normally-seated front-outboard occupant -- none for occupants in undamaged seats and approximately 3% for damaged seats. As discussed in the detailed report, defining rear contacts is difficult from the automated file. Injury sources that could be defined unambiguously as rear include the rear header, backlight area, and pillars rearward of the B-pillar. However, many of the identified injury sources were components that extended both forward and rearward of the occupant -- for example, the roof and side rails; the B-pillar was also classified as an ambiguous source.

The likelihood of injury and the pattern of injuries for damaged and undamaged seating systems especially in rear impacts does not provide clear evidence as to the direction for upgrading the stiffness of seat backs. Possible injuries due to ramping or contacting the rear components are limited. There are a great number of frontal contacts which could be due to rebound and must be considered in any improvement. The seat back is cited as a source of injury in many cases for damaged and undamaged seats. While this percentage is greater for damaged seats, this may be a result of the greater crash severities associated with seat back damage. In any case, because of the high frequency of serious torso injuries and seat back contacts, any change in energy absorption characteristic must consider this direct interaction. The high percentage of head/neck injury also demonstrates the need to consider the head restraint and occupant height along with any **modifications** to the seating system.

2. Hard Copy Studies

To further evaluate how injuries occur and their relation to seat damage in frontal and rear impacts, hard copy cases from the NASS 1988-90 files were selectively reviewed. This work was conducted as part of an agency contractual research project, and results of the study are presented in a report, "Upgrade Seating - Patents, Literature Search, and Accident Analysis," Kennerly Diggs and John Morris, University of Virginia, Prepared fur the National Highway Traffic Safety Administration, September 1, 1992. This NHTSA sponsored research report can be found in Docket No. **89-20-** N03. Three sets of cases were selected as follows.

Set	Impact	No. of Cases	Case Selection Criteria
1	Rear	18	30-39 mph delta-v
2	Rear	31	**AIS 2+** or seat damage
3	Frontal	6	Seat damage

A general discussion of the reviewed cases is presented. Since the cases are unweighted NASS data, the discussion is anecdotal.

a. Eighteen Rear Impact Cases

The 18 rear impact review set encompass all cases in 1988-90 NASS with a rear damage delta-v 30 to 39 mph. Actual impact speed of those cases would be much higher than the delta-v range. For example, **NHTSA's** New Car Assessment Program conducted 35 mph rear impact tests on 1979 to 1981 model vehicles, the delta-v range was 18-26 mph.

The distribution of occupant injuries based on the maximum **AIS** was as follows.

	Front Occupants	Rear Occupants
AIS 0	3	1
AIS 1	12	3
AIS 2	6	
AIS 3	2'	
AIS 4-5	0	
AIS 6	1 (Burn)	
AIS 7 (Unk Inj)	1	

Rear impact caused injuries were at low levels for these severe impacts.

The most frequently injured body part was the head and face, and the highest severity injuries were inflicted to the head and chest. In terms of the probable injury source, steering wheel (9) was the most frequent, followed by the seat back (8), headrest (5), and flying glass (4). However, the number of noncontact injuries (9) was equal to the number of injuries caused by the steering wheel.

In this small sample, 19 of the 29 occupants were restrained. The injury rate for AIS 2+ for restrained occupants is lower than the unrestrained occupants (26% vs. 50% based on unweighted data).

In addition, 11 of 25 front seat occupants suffered injuries from contacts with frontal compartments. Two of these frontal injury cases involved only rearward crash forces.

For seat damage effect, ramping of the occupants was difficult to identify in all the cases. Ramping was clearly not relevant to injuries in 21 of 29 occupant cases. Seat deformation may have contributed to only two of the occupant injuries. In one case, ramping may have contributed to the head injury (AIS 2) from the rear header, and an associated AIS 2 abdominal injury from the safety belt. The other case's relevant injury was at a minor severity level.

On the other hand, rebound may have contributed to injuries in 12 of 25 cases. In many cases, a frontal impact followed the rear impact, thereby adding to the rebound velocity. This is also consistent with the observation that the steering wheel is the most frequent cause of injury. For the most part, the rebound injury was minor.

b. Forty-Nine Rear Impact Cases

The 31 additionally selected rear impact cases had one group with two cases of delta-v greater than 40 mph and the other group with restrained occupants suffering AIS 2+ injuries at any delta-v. To provide a more detailed review of the seat performance, the 31 cases are combined with the already examined 18 cases to become a review of 49 rear impact cases.

Three cases of seat adjuster failure were noted and all were associated with seats deformed by occupant impact. Yet no AIS 2+ injuries from seat adjuster failure could be positively identified from the rear impact cases examined.

Fourteen cases of folding lock failures were reported. Five of the occupants may have suffered AIS 2 injuries that were exacerbated by the failed locks. In four of five cases, the source of the AIS 2 injury is unknown. Thus, the evidence of seat luck failure contribution to injury is unclear.

Two cases of seat anchorage failures were reported. The maximum injury fur the occupants in both of these cases were AIS 1. It appears that seat anchorage failures were not associated with any serious rear impact injuries.

To further examine issues concerning occupant injury vs. seat damage, the analysis concentrated on the seat back yielding issue. The combined 49 cases were divided into two groups - no permanent seat back yielding and permanent seat back yielding. In addition, only injuries of AIS 2+ were included. Thirty-five occupants in the 49 cases met the criteria fur inclusion in this analysis.

In the "no permanent seat back yielding" group, 16 of 17 occupants were restrained. No injuries were identified which resulted from ramping or seat related deformation. However, frontal injuries were present in 8 of the cases. This suggests that rebound may be frequent and the possibility that rebound may have contributed to some injuries.

In the "permanent seat back yielding" group, 16 of 18 occupants were restrained. Seat deformation may have contributed to three of the injuries, and ramping may have contributed to one. However, rebound is also frequently present. Seven of 16 occupants had injuries from frontal sources. Four of the cases were single event rear impacts.

This analysis also examined 8 cases in which vehicles contained rear seat occupants. Some minor AIS 1 injuries could be attributed to the front seat deformation. However, it is not possible from the data to assess the degree to which front seat deformation contributes to the injuries of rear seat occupants.

c. Six Frontal Impact Cases

Six frontal impact cases were reviewed. They involve three seats which are reported to have track/anchorage failures, two which deformed under occupant loading and one which moved forward under impact. From the previously referenced University of Virginia report: "For the seats which were deformed by occupant impact, no contribution of the seat to the injury was evident. However, for the seat that moved forward during a frontal impact and the three track/anchorage failures, seat contribution to the injury severity is possible. In all of these cases, occupants experienced injuries higher than expected for the crash severity. The higher injuries were consistent with those expected from undesirable seat loading of the occupant."

d. Summary of Hard Copy Studies

The agency contractual report summarizes the findings as follows:

> "This preliminary analysis suggests that improvements in seat performance is a more complex matter than simply increasing the strength of the seat back. Legitimate concerns exist over the potential increase in neck injuries and rebound injuries which might accompany strengthened seats.
>
> Harm analysis by Malliaris [Reference: Data Link, 1990] provides insights of injury frequency and severity in rear impacts. His analysis shows that noncontact neck injuries constitute more than 20% of the Harm to restrained occupants. The head restraint is the largest source of contact Harm (17%). The role of head restraints in noncontact neck injuries and contact head injuries needs to be studied in conjunction with any seating system modifications.
>
> Foret-Bruno (91) found a significant increase in head restraint effectiveness as seat back strength in Renault cars was increased to meet the EEC standard. He suggested that the lower-strength, prestandard seats deformed at a force level below that which induces noncontact neck injury. He concludes that strengthened seats are likely to increase the demand on head restraints to mitigate the neck injury risks.
>
> Our data analysis did not permit the quantification of neck injury risks for deformed versus nondeformed seats. In the accident cases we analyzed, we found three noncontact neck fractures in seats which did not deform. No noncontact neck fractures were observed in seats which deformed.

'Rebound' type injuries occur frequently in crashes which involve rear impacts. Malliaris found that 16% of the Harm in rear impact NASS cases was from frontal contacts. In many of the cases, the rear impact is followed by a frontal impact, either in a line of stopped traffic, or by being accelerated into a fixed object. In these cases, and in cases where no subsequent impact occurs, injuries from impact with frontal components of the vehicle are frequently observed. Fur the data set of AIS 2+ injuries in selected rear impacts, injuries from frontal components were believed to be presented in 15 of 35 occupants. It is not possible to determine how many of these injuries were related to the elastic response of the seat, or from other phenomena. However, some seat induced rebound phenomena can be observed in FMVSS 301 rear impact tests. It is evident that the rebound phenomena needs to be researched in conjunction with future seat improvements."

b. Seating System Performance in NHTSA Conducted Tests

1. FMVSS No. 207 Compliance Tests

From the FMVSS No. 207 compliance tests that covered fiscal year (FY) 1972 to 1986, seats in 6 out of 169 (4%) tested vehicle models failed the requirements. For FY 1991, no seats in the 10 tested vehicle models failed the requirements. The compliance test results indicate that FMVSS No. 207's requirements have achieved the intended goals for maintaining a certain minimum performance level for the integrity of vehicle seats. More information about the six seat failure cases is presented as follows*

Model Yr/Make	Model	Seat Failure Description
1972 Toyota	Corona	Front seat back/rear seat back cushion
1972 Ford	Mark IV	Front seat tracks
1974 Ford	Monterey	Rear seat back anchorages
1975 Ford	Mustang II	Rear seat cushion
1982 GM	s-15	Track
1982 GM	c-10	Track

2. FMVSS No. 301 Rear Impact Compliance Tests

To study the performance of production vehicle seat backs in rear impacts, FMVSS No. 301, "Fuel System Integrity," compliance tests were reviewed. FMVSS No. 301's rear impact test requires a 4,000 lb. flat-face rigid barrier crash at 30 mph. It also specifies Part 572 50th-percentile restrained test dummies (uninstrumented) at each front outboard designated seating position.

A total of 54 test reports (FY 1987 to FY 1991) were reviewed. Seat back deflection remaining after the test was measured in terms of degrees of backward rotation from the pre-test orientation. The rotations were measured from post-test photographs in the reports. The following list shows the seat back deflection from those tests. It is noted that significant seat backward rotation in tested vehicle were very frequent.

FMVSS No. 301 Rear Impact Report Review on
Vehicle Seat Back Deflection (Degrees of Rotation)

FY	0 - 10	10+ - 20	20+ - 30	30+	Total Number
87	15.4%	53.8%	23.1%	7.7%	13
88	11.1%	11.1%	44.5%	33.3%	9
89	--	--	60.0%	40.0%	5
90	10.0%	40.0%	10.0%	40.0%	10
91	11.8%	23.5%	47.1%	17.6%	17

To examine occupant's ramping and rebound effects during rear impacts, 12 recent FMVSS No. 301 rear impact test films were reviewed (two-1991 and 10-1992 vehicles). The observed results are presented as follows. From this review, no ramping was observed due to the 30 mph impact and the belt system appears to prevent or reduce the degree of rebound.

FMVSS No. 301 Rear Impact Test Film Review on
Occupant Ramping and Rebound Effects

Model Yr/Make	Model	Ramping	Belt Restrained Dummy Rebound
1991 Ford	Explorer	No	Dummies did not contact belts
1991 VW	Jetta	No	Yes
1992 Mitsubishi	Expo	No	Yes
1992 Toyota	Camry	No	Yes
1992 Ford	C. Victoria	No	? Dummies out of camera's view
1992 Oldsmobile	Royal 88	No	? Same as above
1992 Buick	Road Master	No	? Same as above
1992 Hyundai	Elantra	No	? Same as above
1992 Plymouth	Acclaim	No	? Same as above
1992 Toyota	Paseo	No	? Same as above
1992 Acura	Vigor	No	? Same as above
1992 Plymouth	Voyager	?	? The van has tinted windows

? = Unknown

In summary, from reviewing FMVSS No. 301's 30 mph rear impacts, it appears that front seat backs frequently deform to a high degree but no apparent ramping effects were observed. In addition, it appears that rebound effects were minimized by the use of belt systems.

3. New Car Assessment Program Test

NHTSA conducted 55 FMVSS No. 301 rear impact tests at 35 mph under the New Car Assessment Program (NCAP) on 1979 to 1982 model year vehicles. The tests show that, under the 35 mph test, it was estimated that all the front seat backs rotated backward permanently for more than 30 degrees (13 seat backs rotated 30 to 40 degrees and 80 seat backs rotated 45 to 80 degrees) and must of the front seat backs touched the rear seat back. The legs of all the driver dummies hit the steering wheel, consequently, the driver dummies mainly rotated with the deformed seats. To further study the performance of production vehicle seat backs in rear impacts, films and reports of three NCAP tests that sustained seat back rotation of 60 degrees or more were reviewed. Results are listed as follows.

FMVSS No. 301 Rear Impact NCAP Tests on
Occupant Ramping and Rebound Effects

No.	Model Yr/Make	Model	Ramping	Rebound
(1)	1982 Chevrolet	Cavalier	No (D) No (P)	No (D) Some (P)
(2)	1981 AMC	Spirit	No (D) No (P)	No (D) Some (P)
(3)	1981 Isuzu	I-Mark	No (D) Some (P)	No (D) Some (P)

D = Driver Dummy P = Passenger Dummy
Some = Possible occurrence but nut apparent, decision was based on contact marks on dummy and film observation.

(1) Both dummies' heads contacted the rear seat back. The passenger dummy has a little contact mark on the chin and there is contact mark on the shoulder belt.

(2) The driver dummy's head contacted the rear seat back. The passenger dummy has a line of facial contact mark probably due to contact with the shoulder belt. The rear seat back was pushed up during the impact to meet the dummies.

(3) The driver dummy's head contacted the rear seat back. The passenger dummy's head contacted the roof area above the rear window. There are sume scratch marks on the dummy's face and a little contact mark on the shoulder belt.

NHTSA has conducted 35 mph frontal impacts on vehicles since 1979. Although the focus of this present effort is mainly related to rear impacts, recent NCAP frontal impacts were also reviewed as to seating system performance. From the 1987 to 1991 tested vehicle models, three were identified fur further study from those having seating system damage. The three test results are reviewed and summarized as follows:

FMVSS No. 208 Frontal Impact NCAP Tests on Seating System Damage

No.	Model Yr/Make	Model	Seating System Damage
(1)	1990 BMW	325i	Both seat height adjusters released
(2)	1991 Buick	Century	Both seats shifted forward
(3)	1991 GM	Saturn SL2	Driver seat shifted full forward

NCAP tests on FMVSS No. 208 have instrumented dummies. Responses of the dummies for the three tests are listed as follows:

No.	Head Injury (HIC)		Chest Deceleration		Ave. Femur Loads	
	Driver	Passenger	Driver	Passenger	Driver	Passenger
(1)	1,036	No Data	56g	No Data	859lb.	No Data
(2)	815	1,144	47g	40g	1,177lb.	247lb.
(3)	918	1,018	44g	46g	1,168lb.	1,076lb.

All the dummies had knee contacts with the instrument panel.

(1) The driver dummy's head contacted the deployed airbag and the passenger dummy's head contacted the instrument panel.
(2) The driver dummy's head and chest contacted the steering wheel and the passenger dummy's head contacted the instrument panel.
(3) The driver dummy's head contacted the steering wheel.

In summary, from reviewing the NCAP's 35 mph test impact data, it appears that seats routinely deformed to a high degree in rear impacts. Yet, only limited ramping effects were observed and sume possible minor rebounding was observed. It is also interesting to note the leg contact made with the steering wheel due to the rotation of the dummy in rear impacts. This may account for some of the frontal contacts seen in the accident data. Relatively infrequent seating system damage was observed in frontal impact tests.

E. Defect Investigation Data

NHTSA is responsible for investigating safety related defects on in-use motor vehicles. The agency has received many consumer complaints on seating systems. Between FY 1985 and FY 1992 (August), the agency has initiated 55 investigations due to possible seating system defects. The number of vehicles affected by these investigations amount to 17.5 million vehicles and the vehicle model years are from 1981 to 1992.

The 55 vehicle seat defect investigations relate to 13 cases on seat backs, 11 seat track or anchorage failures, 2 seat track and anchorage failures, and 29 other seat failures. In addition, at least 15 of the 55 cases have indicated that the defective seating system may have resulted in loss of vehicle control. Possible occupant injuries related to the investigated cases are 159 nonfatal injuries and 5 fatalities.

The 55 investigated cases resulted in 9 safety recalls which affected about 3.2 million vehicles and 74 nonfatal occupant injuries. The following two tables show a summary of the 9 safety recall cases which include numbers of complaints received by NHTSA and the affected manufacturers. Attachment 1 provides more details about the 9 safety recalls.

In summary, the agency vehicle seat defect investigations indicate that some seats lost integrity or failed while the vehicles were in operation without any impact. This could indicate an additional seat failure mode due to initial design or construction inadequacies or component fatigue, a failure mode which is not covered in the current standard's requirements.

NHTSA Vehicle Seat Defect Investigations
Safety Recalls Between FY 1985 And FY 1992 (August)

No.	NHTSA Recall Campaign No.	Manufac	Model Yr.	Vehicle Population	Seat Defects
1	89V011000	Chrysler	1985	60,000	Seat Frame (1)
2	86V082000	Ford	1984	195,732	Seat Back
3	87V079000	General Motors	1983 to 1984	1,136,407	Track and/or Anchorage
4	89V170000	Ford	1985 to 1987	1,375,500	Track
5	88V061000	Chrysler	1985 to 1986	1,500	Seat Frame/ Seat Back
6	88V060000	Chrysler (AMC)	1983 to 1984	149,000	Seat Back
7	91V036000	Ford	1988 to 1989	278,000	Seat Fire (Power Seat)
8	88V058000	Utili-master Corp.	1988	10	Track (2)
9	88V147000	Mack Trucks	1982 to 1988	11,000	Seat Tether (2)

(1) Fatigue Failure (2) Faulty Installation

Number of Reported Complaints and Injuries

Manufacturer;	01	02	03	04	05	06	07	08	09	Total
				Complaints						
NHTSA	33	25	25	18	29	18	8	0	1	157
Manufac	83	115	136	50	99	43	50	0	0	576
	116	140	161	68	128	61	58	0	1	733
				Nonfatal Iniuries						
NHTSA	0	6	10	2	1	1	0	0	1	21
Manufac	3	29	16	1	3	1	0	0	0	53
	3	35	26	3	4	2	0	0	1	74

IV. PETITIONS AND REQUEST FOR COMMENTS

A. Petitions

Three recent petitions requested NHTSA to amend **FMVSS** No. 207, "Seating Systems." All the three petitions related to rear impacts. Edward J. Horkey petitioned the agency on March 3, 1988, to look into the "slingshot" effect on restrained occupants. The petitioner suggested that NHTSA amend the requirements for safety belt retractors in **FMVSS** Nos. 208 and 209. Kenneth J. Saczalski petitioned the agency on July 24, 1989, to reexamine the general performance requirements of FMVSS No. 207, in particular, to upgrade the seat back requirements. Alan Cantor petitioned the agency on December 28, 1989, to amend FMVSS No. 207 to eliminate **"ramping"** along a collapsed seat .

The following table summarizes the relevance of the requested amendments from the three petitions to the four previously defined seating system performance issues.' The first issue concerns seating **system** structural integrity, the second issue refers to the energy absorbing capability of the seat, the third issue relates to the compatibility of the seat back with respect to the head restraint, and the fourth issue relates to the safety belt restraint system..

Petition	Issue 1	Issue 2	Issue 3	Issue 4
Horkey	No	**Some**	No	Yes
Saczalski	Yes	Yes	Some	Some
Cantor	Yes	Yes	Yes	Yes

NHTSA granted the three petitions and started the rulemaking actions. The agency published a Request for Comments on

October 4, 1989, seeking comments on the Horkey and Saczalski petitions. The Cantor petition was not in time to be included in the notice, but is included in this review.

NHTSA terminated the rulemaking action of the Horkey petition on October 17, 1990, based on responses to the Request for Comments notice and agency review and analysis. The agency stated in the termination notice that NHTSA was unable to establish that amending the requirements for safety belt retractors would provide any significant safety benefits. However, in the notice, the agency indicated it would continue to examine this issue. Rulemakings on the Saczalski and Cantor petitions are still ongoing.

B. Request for Comments

The Request for Comments notice encompasses all seating system issues raised in the petitions. In terms of the Horkey and Saczalski petitions, the notice asked a series of questions contained in six issues.

- o Seat Back Stiffness in Rear Impact
- o Dual-Mode Sensing Emergency Locking Retractors
- o Costs of Requiring Dual-Mode Emergency Locking Retractors
- o Consumer Acceptance of Dual-Mode Emergency Locking Retractors
- o Other Seat Back Performance Requirements
- o Seat Performance Measurement and Test Requirements

As of March 1, 1992, there were twenty-two (22) entries in Docket No. 89-20, Notice 1 responding to the Request for Comments. Ten (10) entries are from automobile manufacturers (Manufac), six (6) from vehicle safety consultants (Consult), two (2) affiliated with university accident research teams (Univ), one (1) from a contractual report prepared for Transport Canada (Report), and one (1) from a safety belt association (Asso). The remaining two (2) entries are the copies of the two petitions and an NHTSA sponsored research report (Other).

Analyzed Entries in Docket No. 89-20, Notice 1

No.	Doc. Date	Page	Group	Name
002	11/01/89	1	Manufac	Navistar International Trans. Corp
003	11/29/89	6	Manufac	Ford Motor Company
004	11/28/89	2	Manufac	Volvo North Am. & Volvo Car Corps.
005	11/28/89	6	Manufac	Chrysler Motors
008	11/30/89	2	Manufac	Thomas Built Buses, Inc.
009	12/04/89	6	Manufac	General Motors Corporation
013	12/01/89	1	Manufac	Fiat Auto U.S.A., Inc.
014	12/07/89	5	Manufac	Mercedes-Benz of North Am., Inc.
015	12/06/89	4	Manufac	Volkswagen of America,' Inc.
016	12/08/89	4	Manufac	Toyota Motor Corp. Services of Am.
007	11/27/89	7	Consult	Horkey, Horkey & Associates Inc.
011	11/29/89	95	Consult	Saczalski, Environ. Res. & Safety
012	11/30/89	3	Consult	Hoar, Ralph Hoar & Associates
017	12/01/89	2	Consult	Warner, Collision Safety Engr. Inc
022	12/03/91	46	Consult	Shaw, Shaw Research & Consulting
006	11/27/89	1	Univ	Gorski, Accident Research, UWO
019	01/03/90	24	Univ	Macnabb, Accident Research, UBC
010	12/04/89	3	Asso	AORC, Auto. Occ. Restraint Council
018	01/23/90	45	Report	TES Limited, Ontario, Canada

The agency interpretation and analysis of the comments is conducted according to the previously defined four seating system performance issues. They are Issue 1: Seating System Integrity, Issue 2: Energy Absorbing Capability of Seat, Issue 3: Compatibility of Seat Back and Head Restraint, and Issue 4: Compatibility of Seat Back and Safety Belt Restraint.

The comments of the above listed nineteen docket entries are analyzed in terms of the four seating issues and the results are summarized in the following tables. Original entries of the comments are in Docket No. 89-20, Notice 1.

Analysis of Comments
Docket No, 89-20, Notice I, 54 FR 40896

Issue I: Seating System Integrity

No,	Group	Name	Seat Damage Occurs	Damage Causes Occupant Inj.	Upgrade FMVSS 207
002	Manufac	Navistar	--	--	--
003	Manufac	Ford	?	No	No
004	Manufac	Volvo	--	--	No
005	Manufac	Chrysler	?	No	No
008	Manufac	Thomas	No	No	No
009	Manufac	GM	Yes	No	No
013	Manufac	Fiat	--	--	No
014	Manufac	Mercedes	No	No	Yes
015	Manufac	VW	--	--	No
016	Manufac	Toyota	--	--	No
007	Consult	Horkey	--	--	--
011	Consult	Saczalski	Yes	Yes	Yes
012	Consult	Hoar	Yes	Yes	Yes
017	Consult	Warner	?	?	No
022	Consult	Shaw	Yes	Yes	Yes
006	Univ	Gorski	--	--	--
019	Univ	Macnabb	Yes	Yes	Yes
010	Asso	AORC	--	--	--
018	Report	TES Ltd	Yes	Yes	Yes

Notes: -- = No response ? = Doubts expressed by commenter

Analysis of Comments
Docket No. 89-20, Notice 1, 54 FR 40896

Issue 2: Energy Absorbing Capability of Seat

No.	Group	Name .	Current Seating Svs. EA Capabi	Ramping	Seat Back Stiffness	Upgrade 3300in-lb
002	Manufac	Navistar	--	--	--	No
003	Manufac	Ford	O.K.	--	O.K.	No
004	Manufac	Volvo	--	--	--	No
005	Manufac	Chrysler	O.K.	?	O.K.	No
008	Manufac	Thomas	O.K.	No	O.K.	No
009	Manufac	GM	?	Some	?	No
013	Manufac	Fiat	--	--	--	Yes
014	Manufac	Mercedes	O.K.	No	Low	Yes
015	Manufac	VW	O.K.	--	O.K.	No
016	Manufac	Toyota	--	--	--	No
007	Consult	Horkey	--	--	--	--
011	Consult	Saczalski	N.G.	Yes	Low	Yes
012	Consult	Hoar	N.G.	Yes	Low	Yes
017	Consult	Warner	--	--	--	No
022	Consult	Shaw	N.G.	?	Low	Yes
006	Univ	Gorski	--	--	--	--
019	Univ	Macnabb	N.G.	Yes	Low	Yes
010	Asso	AORC	--	--	--	--
018	Report	TES Ltd	N.G.	Yes	Low	Yes

Notes: -- = No response ? = Doubts expressed by commenter
O.K. = Adequate N.G. = Inadequate
Low = Stiffness of current seat back is low
High = Stiffness of current seat back is high

Analysis of Comments
Docket No. 89-20, Notice 1, 54 FR 40896

Issue 3: Compatibility of Seat Back and Head Restraint

No,	Group	Name	Current Head Restraint Sym Problem	Source	Causes Inj	Seat Back Interaction
002	Manufac	Navistar	--	--	--	--
003	Manufac	Ford	No	--	No	--
004	Manufac	Volvo	--	--	--	--
005	Manufac	Chrysler	--	--	--	--
008	Manufac	Thomas	--	--	--	--
009	Manufac	GM	--	--	--	--
013	Manufac	Fiat	--	--	--	--
014	Manufac	Mercedes	--	--	--	--
015	Manufac	VW	--	--	--	--
016	Manufac	Toyota	--	--	--	--
007	Consult	Horkey	--	--	--	--
011	Consult	Saczalski	Yes	?	Yes	Yes
012	Consult	Hoar	--	--	--	--
017	Consult	Warner	--	--	--	--
022	Consult	Shaw	?	?	?	Yes
006	Univ	Gorski	--	--	--	--
019	Univ	Macnabb	Yes	Design	Yes	Yes
010	Asso	AORC	--	--	--	--
018	Report	TES Ltd	Yes	Design	Yes	Yes

Notes: -- = No response ? = Doubts expressed by commenter
Design = The source of current problem is in design

Analysis of Comments
Docket No. 89-20, Notice 1, 54 FR 40896

Issue 4: Compatibility of Seat Back and Safety Belt Restraint

No.	Group	Name	Rebound Effect Rear	Rebound Effect Frontal	Dual-Mode ELRs	Seat Back Interaction
002	Manufac	Navistar	--	--	--	--
003	Manufac	Ford	Some	--	No	--
004	Manufac	Volvo	--	--	Yes	--
005	Manufac	Chrysler	No	No	Yes	--
008	Manufac	Thomas	No	No	Yes	--
009	Manufac	GM	Some	--	No	--
013	Manufac	Fiat	Some	--	No	--
014	Manufac	Mercedes	No	--	Yes	Yes
015	Manufac	VW	--	--	Yes	Yes
016	Manufac	Toyota	No	--	No	--
007	Consult	Horkey	Yes	--	Yes	Yes
011	Consult	Saczalski	--	--	--	--
012	Consult	Hoar	Yes	--	--	Yes
017	Consult	Warner	?	--	--	Yes
022	Consult	Shaw	Yes	--	--	Yes
006	Univ	Gorski	--	--	--	--
019	Univ	Macnabb	Yes	Yes	--	Yes
010	Asso	AORC	--	--	No	--
018	Report	TES Ltd	Yes	--	--	Yes

Notes: -- = No response ? = Doubts expressed by commenter

V. LITERATURE REVIEW ON SEATING SYSTEMS

A. Seating System and Occupant Protection

The modern vehicle seat is generally recognized as a fundamental portion of the total occupant crash protection system. However, the design of belt restraint and head restraint systems have largely progressed independently from the seating systems. Although in recent years vehicle designers and vehicle safety researchers have looked into the interaction of the three systems* the emphasis and the results are not reflected upon the production and occupant injury reduction.

A review of the literature on seating systems in relation to occupant protection resulted in identifying numerous reports and papers. Many of the technological and innovative designs have been or are being considered for incorporation into production seats. For example, the concept of an integrated seat and restraint system was studied in the early 1900s and a patent was awarded in 1903 on the design of an integrated seat with a lap belt and two shoulder belts. Today, General Motors, Ford, Chrysler, and others are all conducting research on cars with seats integrated with restraints. Mercedes-Benz and BMW both offer integrated seats in their production vehicles.

Some of the earliest automotive safety research sponsored by the Federal government was directed to improve seating systems. For example, the Public Health Service sponsored a research program at the University of California at Los Angeles by Severy, et al. The research resulted in an SAE paper, entitled "Backrest and Head Restraint Design for Rear-Collision Protection," SAE Paper #680079 (Starting from 1955, Severy et al, published a series of papers on seating system safety - see bibliography in the previously referenced University of Virginia report (Docket No. 89-20-N03). In the mid 1960s, the Federal Highway Administration funded research at the Cornell Aeronautical Laboratory and at the Highway Safety Research Institute in the University of Michigan, etc. (These are summarized within the above cited report.)

B. Literature Review on Seating System Safety

Through the years, numerous reports and papers have been published on seating system safety. The NHTSA sponsored report ("Upgrade Seating - Patents, Literature Search, and Accident Analysis," Kennerly Digges and John Morris, University of Virginia, September 1, 1992) has a detailed discussion and list of literature on seating system safety. A paper submitted into the NHTSA docket also contains a bibliography on seating system safety publications (Docket No. 89-20-N01-022, by L. M. Shaw).

Because of limitations in time and resources, this literature review on seating system safety only includes some more recent publications. The reviewed publications are summarized as follows.

1. "Response of Belted Dummy and Cadaver to Rear Impact," Final Report, DOT-HS-5-01201, July 1976 and "Response of Belted Dummy and Cadaver to Rear Impact", A. S. Hu, S. P. Bean, and R. M. Zimmerman, Final Report, DOT HS-805-792, December 1980.

In the late 1970s, the agency sponsored research which examined the reaction of dummies and cadavers seated in rigid and yielding seatbacks during simulated rear impact crashes. This research is reported in two documents as listed above.

Sled impact tests were conducted to simulate the motion of a standard size car at rest impacted from the rear by a second car of equal weight travelling at 32 mph. The test subjects were anthropomorphic dummies and unembalmed cadavers. They were seated in a bench seat and were belted and unbelted. In one test mode the seatback was held rigid and in a second test mode the seatback rotated rearward in response to the test subject's loading.

In general, the results indicate lower dummy injury criteria values for the head and chest for the deformable seat back. The head and chest severity indices for the rigid seat back subjects were more severe than those for the deflecting seatback subjects.

The cadavers suffered neck injuries in all except one case -- the one case was a rigid seat back. However, it appears that these injuries are more associated with the placement of the headrest rather than the stiffness of the seat back. The authors indicate that results of the cadaver tests are inconclusive to reach conclusions regarding the relative risk of injuries for deforming vs. rigid seats.

In interpreting these results the characteristics of the rigid and yielding seatbacks should be explained. The yielding seatback utilized a standard bench seat apparently based on a typical Model Year 1975 vehicle. This seat itself was modified to accommodate the installation of the extensive instrumentation utilized in the study. Test data indicated the seatback deflected backward to approximately 40 degrees from the vertical during the sled experiments. The rigid seatback configuration used extensive bracing which resulted in no seatback deflection during the tests. Also, the headrest was placed at the lowest position in most of the test.

The results of this study support the concept of optimizing the seatback energy absorption or deflection characteristic and avoiding designing seatbacks that are too stiff. However, as indicated above, the deflecting seat back utilized in these tests did not show as high a deflection angle as those seen in higher severity crashes. Also, the study demonstrates the need to properly consider the integration of the head restraint and seat back geometry and energy absorption characteristics.

2. "The Minicars Research Safety Vehicle Program Phase III, Volume I - Technical Final Report," V. K. Ausherman, A. V. Khadikar, S. R. Syson, C. E. Strother, and D. E. Struble, Final Report, DOT HS-806-213, September 1981.

This is a report on the NHTSA funded Research Safety Vehicle (RSV) program. The RSV program was to design, build, and test prototypes vehicles that would exhibit advanced safety performance. Minicars, Inc. was one contractor for the RSV program and Calspan, Inc. was another contractor.

In the Minicars RSV, "[t]he front seats are constructed from modified Dodge van seats (1971 to 1976 model year) and are adjustable to accommodate all occupant sizes between a 5th percentile female and 95th percentile male. The seat frame backs carry a thin sheetmetal panel to resist intrusion by the knees of back seat occupants in rear impacts. Each seat frame top is narrowed and attached to a 0.06 inch (1.5mm) thick clear Lexan sheet. The Lexan sheet, in turn, is connected to the roof, which substantially improves the seat's structural strength in rear impacts. The Lexan attachment to the seat frame incorporates mild steel tape force limiters which provides 700 pound (320 kg) load limiting. The foam seat cushions are also narrowed, then built up with additional foam to form a more desirable contour. All four seats, frontal and rear, are covered with standard automobile vinyl."

The modified Dodge van front seats use Volvo seat tracks for fore and aft adjustment. There are no belt restraints for the frontal seats. "Sled and crash tests have demonstrated that this seat not only is extraordinarily crashworthy, but also correctly and comfortably positions drivers ranging from 5th percentile females to 95th percentile males." The test results include measurements of dummy responses (head and chest accelerations, knee contact forces) and calculation of HIC and CSI.

3. "A Preliminary Evaluation of Seat Back Locks - For Two-Door Passenger Cars With Folding Front Seatbacks," Charles J. Kahane, NHTSA Technical Report, DOT HS-807-067, February 1987.

This is an effectiveness evaluation report on part of FMVSS No. 207, "Seating Systems." The evaluation is limited to only the part of the standard that contains requirements concerning seat back locks (Section S4.3. Restraining device for hinged or folding seats or seat backs). In particular, the evaluation determines if seat back locks are effective in reducing deaths or injuries and measures the actual costs of the locks.

The evaluation is based on statistical analyses of three States, FARS, Multidisciplinary Accident Investigation data, sled test analyses, and a cost study of production lock assemblies. The evaluation indicates that seat back locks hold seat backs in place in crashes when the back seat is unoccupied, but locks or other seat components often separate at moderate crash speeds when there are unrestrained back seat occupants. The report also presents data from a series of sled tests and accident data that indicate that in frontal impacts there is a high percentage of seat hardware and/or anchorage breakage.

The report concludes that there are no statistically significant injury or fatality reductions found for seat back locks from the studies. The locks add about $14 (1985) to the lifetime cost of owning and operating a car. However, the report cautions that in using statistical analyses it is easy to prove definitively that a safety device is effective but difficult to prove that it is nut. Hence the report is labeled as a "preliminary" evaluation.

4. "Evaluation of Seat Back Strength and Seat Belt Effectiveness in Rear End Impacts," Charles E. Strother and Michael B. James, Collision Safety Engineering, Inc., SAE Paper #872214, Proceedings of the 31st Stapp Car Crash Conference, New Orleans, LA, October 9-11, 1987.

This paper is to determine whether or not there is any merit in the concept of "rigidizing" (stiffening) seat structures for rear impact and, whether seat belts are of benefit in these collisions. To achieve the objectives, the authors first review prior research on rear impact, then evaluate data of laboratory tests of current production seats, and finally examine current accident statistics.

For prior research on seat safety, the authors reviewed literature covered 25 years, beginning in the mid-1950s. They divide the literature into three basic types: experimental, mathematical, and other. They examine only the first two types and try to answer three questions: (1) In comparing yielding seats to rigid seats, is there any safety advantage to either design? (2) Is a rigid seat practical?, .and (3) Are seat belts effective in rear impacts?

The authors conclude that occupants in rigidized seats experience significantly higher injuries than yielding seats with "controlled yielding" of the seat back. The rigid seats result in more ramping and whiplash related occupant injuries with or without head restraints and lap belted or unrestrained. In addition, an occupant's response in rigid seats is very sensitive to impact conditions (occupant's position at impact, etc.).

From the review of the history of rigid seat development and test data, the authors conclude that rigid seats are impractical due to excessive weight and cost. Rigid seats would lead to technical and biomechanical complications and could be effective only with a belted occupant population and adequate head restraints.

The authors conclude that seat belts are effective in rear impacts, particularly when delta-v exceeds 15 mph. In addition, restraints tend to minimize the motion of the upper body relative to the seat back and help control rebound motion.

From conducting static tests on production seats, the authors conclude that production seats are capable of producing restraining forces significantly above the requirements of FMVSS No. 207. From reviewing NHTSA conducted NCAP rear impact tests, the authors state that permanent seat back deflection can be expected of virtually all production seats at impact severities of delta-v of 15 mph or greater.

From examining accident statistics for rear impacts, the authors indicate that occupant injury resulting from this impact mode is significantly less than that associated with frontal and side impacts. Finally, they state that from all indications the most effective and practical means to reduce rear impact injury is the use of available seat belt restraint systems.

This paper provides results of static seat tests on production bucket seats conducted by *Severy* et al and the authors (Table 1). *In* addition, this paper provides results of rear impact tests on production vehicles for examining dynamic characteristics of seats (Appendices A, B, and C). Those crash tests were conducted by Severy et al, NHTSA, and others. Accident data collected from *FARS* and NCSS are presented.

5. "Accidents Involving Seat Back Failures," TES Limited, Kanata, Ontario, Prepared for the Ministry of Transport Canada, Report No. C1322/2, December 1989.

This is a contractor's report conducted by TES Limited for the Canadian government. This report was submitted to NHTSA Docket No. 89-20-N01-018. The study involves the examination of 23 real-world case reviews in which passenger cars have experienced seat back failures. Many of the cases involve very severe crash severities and involve vehicles that experienced considerable rotation and multiple crashes during the impact. However, there were a number of cases that were examined where the seat back was damaged during normal operation without any crash event.

This study indicates that seat backs fail mostly due to the occupant's weight on the seat back in rear impacts and some are due to the occupant's weight while the vehicle is stationary or traveling at a constant speed. The two most common types of failure are from the seat back support system -- locks and hinges and the deformation of the seat back frame.

The study specifically addressed the question of the effect of seat back failure on passenger ejection. Of the twenty-three cases examined, eleven of these resulted in one or more of the passengers being ejected from the vehicle. Most of these cases involved multiple impacts and rotation and appear to be of a high severity. About half the occupants that were ejected were using their restraint system. The report indicates: "It is, therefore, apparent that if seat back failure occurs, the use of the restraint system may not prevent the occupant from being ejected from the vehicle". The report indicates that in several of the cases the ejection would probably have been avoided if the seat back had remained in an upright position when loaded by the occupant during the collision.

The report indicates that in three cases in which major injuries were sustained, there were two occupants in the vehicle in which one seat back failed but the other did not. In all three cases 'the occupant of the failed seat suffered major or fatal injuries, while the occupant of the other seat suffered only minor injuries or no injuries at all.

Three cases involve rear seat passenger injuries due to the collapse of front seats or head restraints. In one case, the left rear passenger was fatally injured by the detached head restraint of the driver's seat, another case involved the right rear passenger who suffered minor injuries when the right front passenger's seat back collapsed, and the third case involved the right rear passenger who was fatally injured and was probably impacted by the driver during his ejection from the driver's seat.

6. "Current Issues of Occupant Protection in Car Rear Impacts," Technical Memorandum, DTRS-57-87-C-00117 (Task #6), prepared by Data Link, Inc., February 1990

This NHTSA funded report was prepared by Data Link, Inc., in February 1990, as part of the agency's investigation into the safety problem related to rear impacts.

This report utilized the agency's NASS 1979-1986 data files and analyzed rear impacts in both an aggregate and clinical method.

As to seat back "failure" or "collapse," the study found that it is quite frequent in rear impacts.

In examining the NASS data the report indicates the following:

"The harm proportion assigned to occupant contacts with the rear compartment is higher in rear impacts than it is in all other impacts. Although this is not unexpected, we observe that the proportion in question is small and rather insignificant by comparison to other sources of injury shown in Table 13." Table 13 assigns 2.8% of harm to rear injury sources compared to 42.2% for noncontact and 16.1% for frontal injury sources.

In examining ejection, the report presents a table that shows that injury from ejection in rear impacts account for about 3% of the total harm. This compares to about 19% for all other modes. "It is evident in the results shown in this table that ejections are not a particularly significant problem in rear impacts, per se or in comparison with ejections in other impacts."

In specifically examining selected cases -- high injury and/or damage in rear impacts -- the report presents a series of tables and concludes the following: "The dominant source of injury is "noncontact", and there are substantial proportions assigned to seatbacks and head restraints, as expected." It continues: "In the case of front seat occupants, irrespective of restraint status, about 15% of the harm is assigned to contacts with frontal interior surfaces and components. A part of this harm might be associated with the 'rebound effect'."

In regard to safety belt effectiveness in rear impacts, the report concludes that the effectiveness is about 40% in the reduction of harm.

7. "Occupant Protection in Rear-End Collisions: I. Safety Priorities and Seat Belt Effectiveness," Michael E. James, Charles E. Strother, Charles Y. Warner, Robin L. Decker, and Thomas R. Perl, Collision Safety Engineering, Inc., SAE Paper #912913, Proceedings of the 35th Stapp Car Crash Conference, San Diego, CA, November 18-20, 1991.

This paper reports the results using four published accident data reports which examined injuries associated with rear impacts. The four reports are (1) a December 1987 report, "Fatalities in Rear-Impacted Small Cars from 1982 through 1987," Susan C. Partyka, one of the four papers in the report, "Papers *on* Vehicle Size -- Cars and Trucks," Page 125, DOT HS-807-294, NHTSA Technical Report, June 1988; (2) a 1989 Data Link report, "Car Crash Outcomes in Rear Impacts," NHTSA supported research report, July 1989; (3) another Data Link report, "Current Issues of Occupant Protection in Car Rear Impacts," NHTSA supported research report, 1990 (also has been reviewed separately in this section); (4) a 1990 Peugeot/Renault supported report, "Risk of Cervical Lesions *in* Real-World and Simulated Collisions," Foret-Bruno, J. Y., et al., the 34th AAAM Conference Proceedings, Scottsdale, Arizona, Page 373, October 1990.

These accident data studies show that rear impacts do not account for a significant portion of automobile injuries; current production seat backs, provide a high level of protection in rear impacts; and the injury mechanisms which may be addressed by rigid seats make up a minuscule proportion of rear impact injuries.

These accident.data also provide additional information on the effectiveness of seat belts in rear impacts. Reductions in Societal Harm or injury of 37% to 47% are indicated.

> 8. "Occupant Protection in Rear-End Collisions: II. The Rule of Seat Back Deformation in Injury Reduction," Charles Y. Warner, Charles E. Strother, Michael B. James, and Robin L. Decker, Collision Safety Engineering, Inc., SAE Paper X912914, Proceedings of the 35th Stapp Car Crash Conference, San Diego, CA, November 18-20, 1991.

The authors indicate that this paper is partly in response to NHTSA's Docket No. 89-20, in relation to FMVSS No. 207, "Seating Systems." They intend to arrive at an appropriate seat design philosophy by comparing the appropriateness of a rigid seat design and a controlled yielding seat design.

The approach is to review the legislative history of seating systems standards, production seat characteristics, and rigid seat back concerns in real-world rear impacts - ramping and rebound effects.

The paper states that the rulemaking history of "seat design" standards indicates that the concept of yielding, energy absorbing seat backs has always been considered the appropriate design approach for passenger cars. Research findings associated with the rulemaking efforts confirm that rear impacts do not represent a substantial contribution to occupant injuries, and that yielding seat backs can provide occupant protection.

The paper reviews static test data of 61 production seats. Forty-eight of them are from previous tests (SAE Paper #872214 which has been reviewed in this section.) and 13 new tests. They state that , the static tests indicate that the strength of production passenger car seats has not substantially changed over the past three decades.

The paper discusses three most important concerns related to rigid seat backs - ramping, rebound, and out-of-position occupants. The authors indicate that since frictional coefficients between occupants and seat backs decrease dramatically with increasing pressure on the seat backs, ramping will occur on rigid seat backs at lower rotation angle from vertical. They indicate that rigid seat backs have to be built on seats with adjustment features due to practical considerations. During rear impacts, adjustable rigid seats will store more elastic energy than non-adjustable seats, therefore, will cause more rebound. Finally, they indicate that "[i]mpacts with a yielding seat back structure by an out-of-position occupant would be expected to be of reduced severity because of the energy absorbing properties of the yielding seat."

Based on the reviews, the authors conclude that rigid seat backs have the potential to increase injury exposure in real-world impacts due to the above discussed three major concerns:

(1) Rigid seats have the potential of exposing unrestrained occupants to impacts with the roof structure in severe rear impacts. Ramping can be expected with seat back angles as low as 25 degrees from the vertical.

(2) Non-yielding seats, particularly those with adjustable seat backs, can increase occupant rebound because all of the seat deflection will represent elastic energy which will be returned to occupants in the form of rebound velocity. Injuries associated with rebound include whiplash and contacts with frontal vehicle components.

(3) Rigid seats are potentially dangerous *to* occupants not in the "Normal Seated Position," especially unrestrained occupants. A majority of rear-impacted vehicles experience pre-impact changes in momentum which could cause occupants to be out-of-position at impact.

9. "Influence of the Seat Belt and Head Rest Stiffness on the Risk of Cervical Injuries in Rear Impact," J. Y. Foret-Bruno, F. Dauvilliers, and C. Tarriere, Report No. 91-S8-W-19, the 13th ESV Conference, Paris, France, November 4-7, 1991.

Rear impacts are statistically less frequent and severe than other collision modes based on an analysis utilizing French accident data files. Cervical injuries are the most frequent injury -- 27% of the cases. Cervical injuries are mostly minor (AIS 1). This is the case in 99% of the cases. In 1% of the cases these injuries are severe, including fractures of the cervical vertebrae.

Recent studies by Renault indicate that head restraints are 30% effective in reducing neck injuries. This effectiveness was calculated at up to 60% for newer vehicles.

Information indicates that newer vehicles have a lower frequency of seat back breakage. At above 25 km/h, 1971 to 1976 vehicles have a breakage frequency of 62%, whereas 1977 and newer models have a breakage frequency of 55%. It is indicated that the head rest has become more effective because seats have become stiffer. Thus, they conclude that the systematic installation of head rests in all vehicles was a good initiative.

Their accident data indicate that the risk of cervical injury in current seat types is highest without head rests mainly when the seat back does not break. For seats that had head rests, the risk of cervical injury appears similar for seats with and **without** breakage. This is true throughout the different vehicle age categories.

A series of experimental sled **tests** utilizing the Hybrid III dummy were performed. Tests simulated a 15 km/h impact. Parameters studied included variations in the effect of head rest and seat back stiffness. The results indicate "that the head rest, **no** matter what its position in relation to the head, and no matter whether it held under the force exerted by the head, reduces the must predictive criteria of cervical injury".

The report indicates that the most predictive criteria are shear force and **flexion** torque. The tension force (pull on the neck) and the extension torque are also given.

For seat back stiffness differences, it was indicated that utilizing the **"experimental"** head rest, the most predictive criteria were similar for both the stiff and normal seat backs. The pull force (tension force) was reduced with the stiff seat back.

10. "Upgrade Seating - Patents, Literature Search, and Accident Analysis," Kennerly Digges and John Morris, University of Virginia, prepared for the National Highway Traffic Safety Administration, September 1, 1992.

This report describes current research sponsored by the agency. The report is included in **NHTSA's** Docket No. **89-20-N03.** It also reviews selected literature, including some of the earliest studies performed on this subject by Severy and the Cornell Aeronautics Laboratories.

VI. SUMMARY

The primary safety concerns being raised regarding seating system performance relate to the possibility of increased risk of injury when the seat back is damaged in rear impacts. The damage to seating systems in real-world collisions has been characterized as seat **"failure"** and the solution proposed by some of the petitioners and other commenters on this subject relates to increasing the strength of the seat back. The analyses presented in this report indicates that improvements in seating system performance is more complex than simply increasing the strength of the seat back. Legitimate concerns exist over the potential increase in certain types of injuries that might be associated with strengthened seats. As indicated in several of the reports evaluated, a proper **"balance"** in stiffness and compatible interaction with head and **belt** restraint systems must **be** obtained to ensure optimal injury mitigation.

To assist *in* sorting out the information on this complex issue, specific seating system performance issues were identified from the literature review presented in this report. The first category is concerned with seating system integrity. This refers to the structural integrity of the seat and its anchorage to the vehicle structure. The second category of issues refers to the *energy* absorbing capability of the seat itself. The energy absorbing capability is characterized by the stiffness of the seat back. It includes not only the manner in which the seat back absorbs energy but also the manner in which it releases energy. It is the structural integrity and energy absorbing issues that are the primary focus of the rulemaking petitions and public interest.

The third category of issues relates to the compatibility of the seat back with respect to the head restraint, and the fourth category relates to the compatibility of the seating system and the safety belt restraint system. These two issues may relate to FMVSS No. 202 on the head restraint and FMVSS Nos. 208 and 209 on the safety belt restraint system.

Also, it should be stressed that while the current concern has been focused on rear impacts, the seating system must function properly in all crash modes. Thus, the four performance issues discussed must be evaluated not *only* for rear impacts but, also, frontal, side, and rollover crashes.

The agency's National Accident Sampling System (NASS) was utilized to examine the performance of seating systems in real-world collisions. Analyses were conducted to identify any differences in injury risk between occupants of damaged and undamaged seats. Since both the likelihood of seat damage and injury increase with crash severity, the only way to examine a possible causal relationship between seat damage and injury is to control for crash severity. In interpreting the results of these analyses, it should be cautioned that some of the results may not be statistically significant *since* the sample size is fairly small especially after controlling for crash severity. The analyses were conducted separately for each crash mode. For rear impacts, the results were mixed. For low crash severity crashes, occupants of damaged seats had higher injury rates than occupants of undamaged seats. However, for the higher crash severities, the occupants of damaged seats had lower injury rates. *In* frontal crashes, the results were more consistent. In all ranges of crash severity the occupants of damaged seats had higher injury rates.

The real-world collision data utilizing NASS also does not indicate a greater likelihood of ejection with or without seat damage. However, from information and reports presented in the docket, based *on* analyses of selected individual collisions with seat damage, there are indications of ejection associated with seat damage in rear impacts. The data do not indicate that occupant "ramping" up a damaged seat is a major concern vis-a-vis exposure to rear components. There are data to support the concept of "rebound" into the frontal components after rear impacts. However, the evidence of this phenomenon does not suggest a significant safety problem and is based primarily on minor injuries received from contacting frontal components. But it does indicate that any stiffening of the seat back must consider this phenomenon.

The real-world collision data do not support any concern related to the operation of safety belt systems. Further, it should be cautioned that many of these frontal contacts are not due to rebound off the seat, but could be attributable to secondary frontal impacts or contact with frontal components as the occupant is rotating back in response to rear impact forces. These analyses also reinforce the need to evaluate head restraint' performance along with any changes in seat back stiffness.

The laboratory data evaluated in this report demonstrate that a proper balance in stiffness must be achieved to obtain optimal safety results. Again, the laboratory data are inconclusive in indicating any evidence that seating systems are not performing appropriately. Most of the laboratory efforts have utilized dummies which were not developed to simulate rear impact kinematics. The research does support the need to address both the head restraint and seat back performance together.

The agency's compliance and New Car Assessment Program rear and frontal crash tests are analyzed as to seating system performance. The tests indicate frequent seat damage in rear impacts due to dummy loading. The production vehicle seats all rotated backward permanently and most of them touched the rear seat backs when subjected to 35 mph rigid barrier rear impacts. The results of this review did not indicate a problem with ramping, but did indicate potential rebound problems. No problems were noted with the operation of the safety belt in the rear impact tests. Damage , in frontal impacts was rare and involved seat hardware or anchorage breakage. The frontal NCAP tests indicate that the loss of seat integrity exacerbates the dummies' injuries.

A review of the agency's consumer complaint and recall files indicated several cases of seat back collapse under normal driving conditions without any crash event. Some of the seat defects are not crash related, but they may cause the driver to lose control of the vehicle while the vehicle is in operation.

In reviewing the responses to the agency's public request for information on this subject area, the responses were mixed. Debate continues as to whether today's production seats provide appropriate performance characteristics to minimize injuries. In general, the vehicle manufacturers indicate that the seating system is performing adequately and that the standard dues not need to be upgraded. They indicate that a safety need has not been demonstrated, and that stiffening seat backs may create additional problems. Several accident investigators and researchers have presented case study information on cases involving occupant injuries in vehicles with damaged seats. Most of the arguments utilize the same available accident files, tests, and reports to arrive at different conclusions. The agency cannot clearly conclude the issue based on the comments.

From the literature review, the difference in judgment on the performance of seating systems continues the debate. There is the view that seat backs should be designed to have a "controlled yielding" for energy absorption. However, the literature does not have practical designs for "controlled yielding" seat backs. There is another view that seat backs should be designed rigid enough to resist rotating backward and to prevent ramping. Both design ideas are with merit with appropriate limitations and is why many researchers indicate designs must strive for a proper "balance" of these characteristics. The characteristics refer to a consideration of the four issues discussed in the previous paragraphs on structural integrity, energy absorption, head restraint compatibility, and safety belt restraint compatibility.

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Seat Damage and Occupant Injury in Passenger Car Towaway Crashes

Susan C. Partyka
Office of Vehicle Safety Standards, Rulemaking
National Highway Traffic Safety Administration

June 8, 1992

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Seat Damage and Occupant Injury in Passenger Car Towaway Crashes

Susan C. Partyka
Office of Vehicle Safety Standards, Rulemaking
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Summary

This report describes an exploratory data analysis of seat damage and occupant injury performed to provide insight into injury mechanisms, to suggest questions for further research, and to help establish the safety priority of these questions. Occupant involvements and injuries were estimated from a statistical survey of towaway crashes, and these estimates are subject to sampling and nonsampling error. Estimates of sampling variability are beyond the scope of the present effort, and no claims of statistical significance are implied by the comparisons made here.

Ten percent of occupied front-outboard seats (the driver and right-front seats) in passenger cars involved in towaway crashes from 1988 to 1990 were permanently deformed (by occupant impact or intrusion) or their hardware was damaged in the crash (the seat adjusters, folding locks, tracks, or anchors were broken), for an average of 321,000 occupied seats damaged a year. Seat deformation was more common than broken seat hardware, and in one year:

135,000 (42 percent) seats were deformed by vehicle intrusion,
113,000 (35 percent) seats were deformed by occupant loading, and
74,000 (23 percent) seats had broken hardware.

Data from 1978 and 1979 suggest that at that time more deformed front seats were loaded by rear-seat occupants than by occupants of the front seat itself, even though most towaway crashes did not involve rear-seat occupants. The 1988 to 1990 data do not describe which occupant loaded a deformed seat, but some confirmation of the earlier result is found in the association between front-seat damage and rear-seat occupancy. An occupied front seat in a towaway crash was more likely to be damaged if there was a rear-seat occupant immediately behind it. The proportion of seats damaged was:

10 percent when there was no occupant seated behind,
18 percent when there was one occupant seated behind, and
29 percent when there were two or more occupants seated behind.

Seat damage was more common in rear impacts than in other towaway crashes. In side impacts, seats on the impacted side (near-side crashes) were damaged more frequently than seats away from the impact (far-side crashes). In recent (1988 to 1990) towaway crashes,

38 percent of seats in rear impacts were damaged,
19 percent of seats in near-side impacts were damaged,
9 percent of seats in rollover crashes were damaged,
7 percent of seats in far-side impacts were damaged, and
5 percent of seats in frontal impacts were damaged.

The type of seat damage differed by impact type. Deformation from occupant loading caused 42 percent of the seat damage in frontal impacts and 71 percent in rear impacts, Deformation from vehicle intrusion caused most seat damage in side impacts: 90 percent in near-side impacts and 71 percent in far-side impacts, The most common seat damage in rollover crashes was broken folding locks (40 percent of the damaged seats).

The frequency of seat damage did not vary greatly by seat type (that is, for bucket and bench styles, with or without a folding back) or vehicle curb weight, but there were differences by vehicle age. A larger fraction of seats in the older cars involved in towaway crashes from 1988 to 1990 were damaged, and the pattern was clearest in front and rear impacts. These patterns may reflect vehicle design changes, vehicle aging effects, or differences in vehicle use (including differences in crash speed) between newer and older *cars.*

In rear impacts, heavier occupants were more *likely* to have their seats damaged; the pattern was less clear in frontal impacts. Belts were used *more* often in undamaged than in damaged seats, possibly because belt users tended *to* be involved in lower-speed crashes. It is not clear from these data whether belt use reduced occupant-induced seat deformation and hardware damage in some crashes by restricting occupant movement, but less-frequent belt use in damaged seats is consistent with this possibility. Among unbelted occupants, ejection was more likely in damaged than in undamaged seats in rollover, frontal, near-side, and far-side impacts; again, this difference may reflect the more-severe crash forces associated with seat damage. *In* rear impacts, the estimated ejection risk was lower in damaged than in undamaged seats) but these estimates are based on a small number of cases.

Injury risk was greater in damaged seats, largely because seat damage tends to occur in higher-severity crashes. Less-frequent belt use and more-frequent ejection in damaged seats also contributed to higher injury risk. It is difficult to estimate the incremental effect of seat damage on occupant injury because crash severity increased the risk of both damage and injury. This may be particularly true in side impacts, where most *seat* damage was caused by intrusion. Occupants in the rear seat also tended to be injured more often (especially from contact with the front seatback) when the seat directly in front of them was damaged in the crash. Again, this association may reflect severe crash forces that led to both front-seat damage and injury to the rear-seat occupant, For example, some rear-seat occupants may have been forced against the front seatback by crash forces, causing both seat damage and injury from seatback contact.

Injury risk comparisons are more meaningful after accounting for differences in crash severity. In frontal crashes, occupants of damaged seats were more likely to be injured than were occupants in undamaged seats for each 10 mile-per-hour (mph) range of delta V. It is not clear from these data whether stronger seats would have prevented injury, because crashes in which seats were damaged may dkffer in important ways from other crashes with similar delta Vs. Differences in the likelihood of injury between damaged and undamaged seats were greatest for the less-severe frontal crashes, and *any* effect of seat damage on injury may also depend on crash severity.

Injury comparisons for other impact types were limited by the small number of cases in each 10 mph range (this was the case for rear impacts), the lack of a good crash severity measure (for rollover crashes), and the likelihood that seat damage acted (at least in part) as a surrogate for the extent of passenger compartment intrusion and the likelihood of direct injury from this intrusion (for side impacts).

Data

The 1988 to 1990 National Accident Sampling System (NASS) describes vehicle damage (including permanent seat deformation and other seat damage) and occupant injury in light vehicles that were towed from the scene because of damage received in the crash. The NASS sites were randomly selected from the nation and cases are selected randomly in-each site, so the weighted NASS data are national estimates of light vehicle towaway crashes. The 1988 and 1989 NASS data were weighted using the simple inflation factors; the 1990 data were weighted using the ratio-adjusted inflation factors. The resulting estimates include both sampling and nonsampling errors, as do all surveys.

The NASS weighting factors are, in general, noninteger; the weighted counts were rounded to integers for this report, causing some apparent small inconsistencies in the totals. Some NASS cases were selected for special study rather than for statistical estimation; they are included in the case count, but have a weighting factor of zero. Estimates based on a small number of cases (as indicated in the tables presented here) can only suggest national totals. Some data are difficult to obtain and are frequently missing: NASS estimates that require detailed information are low unless the estimates are adjusted for missing data. The NASS totals presented in the tables in this report have not been adjusted for missing data, but the percentages provided have been calculated from the known data.

The scope of this report is occupants of towed passenger cars, defined as NASS Body Types 1 to 9. Vehicle impacts were described as rollover or nonrollover; nonrollovers were described further by the primary damage area. ***Rollover crashes*** are those in which the car rolled over at least one quarter turn, regardless of the timing or severity of the rollover event. Rollovers can be identified from a variety of sources (including a vehicle inspection, police report, or interview), but the damage area can be determined only from a NASS vehicle inspection. The damage area was defined from the primary (most severe) General Area of Damage (GAD) in the groups: front, near-side (drivers in left-side impacts and right-front passengers in right-side impacts), far-side (drivers in right-side impacts and right-front passengers in left-side impacts), rear, and other (top and undercarriage, combined). The damage area was unknown for some inspected vehicles, including those repaired before inspection and some with complex, multiple-impact events.

The damage extent zone describes vehicle crush on a scale of one to ***nine.*** This measure was known for all identified frontal, near-side, far-side, and rear nonrollover impacts because GAD and extent zone are coded together as part of the Collision Deformation Classification (CDC). The extent zone for the most severe damage to a rollover vehicle was known only if the CDC was completed. The primary extent zone for rollover vehicles need not reflect the rollover event itself, but might reflect an earlier or later nonrollover impact. Extensive vehicle damage was defined for this report as damage to extent zone three or beyond. Crash severity is measured by delta V, which is an estimate of the change in velocity during impact.

Injury severity was defined in terms of the maximum Abbreviated Injury Scale (AIS) value for each occupant, categorized as: no injury, minor injury (AIS 1 survivor), moderate injury (AIS 2 survivor), and serious injury (AIS 3 to 6, or fatality). Occupants for whom it was unknown whether they were injured were considered uninjured; surviving occupants who were injured with unknown severity were considered to have suffered minor injury. The moderate and serious injury rates were defined as the fraction of involved occupants with at least moderate or serious injury (including fatality), respectively.

Individual moderate and more severe injuries were described using the Occupant Injury Classification (OIC) body regions and the associated injury contact source. Body regions were categorized into five groups using the OIC.

Body Area	OIC Body Region
Head-neck	H, F, N
Torso	B, C, M, P, S
Arm	A, E, R, W, X
Leg	K, L, Q, T, Y
Unknown	O, U

Injury contacts were grouped by whether the contact was forward or behind a normally-seated front-seat occupant, in order to identify injuries that might not have occurred in an undamaged seat. Front components include (but are not limited to) the windshield, instrument panel, and front floor area; rear components include the rear header, backlight area, and pillars rearward of the B-pillar. The distinction between front and rear components could not be made for many identified components (such as the B-pillar, side rails, and roof) because the injury contact codes do not specify in enough detail their location in relation to the pre-crash occupant seating position.

Injury Source Area	NASS Injury Contact
Front component	1-16, 20-22, 25, 30-32, 35, 50, 56-59
Rear component	24, 34, 51, 60-62
Seatback	40, 44
Insufficient detail	All other coded
Unknown contact	97

The NASS definitions for all data elements used in this report are described in detail in the investigators' reference manuals (*National Accident Sampling System 1988 Crashworthiness* Data System *Data Collection*, Coding *and* Editing *Manual* (National Center for Statistics and Analysis (NCSA), National Highway Traffic Safety Administration (NHTSA), DOT-HS-807-196, January 1988; and the corresponding versions for later years),

The only other statistical source of detailed seat damage information is the National Crash Severity Study (NCSS) data collected from April 1978 to March 1979. The NCSS data describe the location, direction, and cause of all seat intrusions (for occupied and unoccupied seats), as well as vehicle damage and occupant injury. The NCSS data are described in *NCSS -- The Analyst's Companion: A Description of the National* Crash *Severity* Study *Statistical* Data *File* (S. Partyka, NCSA, NHTSA, DOT-HS-805-871, May 1981). The NCSS cases *were* selected by probability methods at eight team sites by seven teams, but the sites were a judgment sample from areas with experienced investigators. The NCSS data may not represent the national experience, but they are generally accepted as useful descriptions of the relationship between vehicle damage and occupant injury.

Crude (order-of-magnitude) national estimates were made from the weighted NCSS data in order to put the results in some perspective. The scaling factor used was the ratio of car occupant fatalities in the Fatal Accident Reporting System (FARS; Body Types 1 to 4, and 6 to 9) to the number investigated by NCSS during these twelve months (NCSS Body Types 1 to 3). The early FARS data are described in *the Fatal Accident Reporting* System User's *Guide* (NCSA, NHTSA, unpublished document, August 1981).

Frequency of Seat Damage

The three years of NASS described here include 25,310 front-outboard car occupants, of whom 19,719 were in cars that were at least partially inspected (Table 1). No adjustments for missing inspection, vehicle damage, or occupant injury data have been made in the tables, and the simple weighted data (shown in all tables) tend to underestimate the number of national occurrences unless such adjustments are made. For example, the weighted data on seat performance might be adjusted by a factor of 1.32 to account for uninspected vehicles, under an assumption that vehicle inspections are missing at random. The rest of this report describes the data obtained from inspected vehicles.

Table 1: Vehicle Inspections for ***Front-Outboard*** **Occupants**
(1988-1990 NASS Towed Cars)

Inspection Type	Actual Cases	Weighted Number	
None	5,591	2,322,336	24%
Complete	15,692	5,572,400	58%
Partial	4,027	1,564,550	16%
Total	25,310	9,549,285	100%

Seat,performance was unknown for three percent of the occupants of inspected vehicles. An estimated ten percent of these occupants had broken seats or seats with other crash-induced residual deformation (Table 2), and these outcomes are referred to collectively as ***sear damage*** in this report; seat bending that does not result in permanent deformation or other damage is not identified by NASS. Seat damage includes broken seat components (seat adjusters, seat back folding locks, tracks, and anchors), occupant impact deformation, and deformation caused by vehicle intrusion into the passenger compartment. The remainder of this report is based on seated occupants (excluding the thirteen investigated occupants without a seat at their location).

Table 2: Seat Performance **for** Front-Outboard Occupants
(1988-1990 NASS Inspected Towed ***Cars)***

Seat Performance	Actual Cases	Weighted Number	
No seat	13	4,747	
No damage	15,694	6,247,064	90%
Damaged	3,598	705,401	10%
Unknown	414	179,738	
Total	19,719	7,136,950	100%

The annual number of front-outboard occupants in seats damaged in towavay crashes (adjusted for missing vehicle inspections and unknown seat damage) can be estimated from the proportion implied by Table 2,

$$\frac{705{,}401}{4{,}747 + 6{,}247{,}064 + 705{,}401},$$

applied to the 9,549,285 front-outboard occupants involved in the three years included here (Table 1) -- which suggests about 321,000 damaged seats a year. Damage to unoccupied seats is not reported on the computer file, but the information was collected during the vehicle inspection and is available on the completed NASS data forms. Seat damage type was also handwritten on the 1988 and 1989 NASS forms, but not automated; seat damage type for these years can be determined only by reviewing the forms. The specific type of seat damage was automated beginning in 1990, and these data are described later in this report. Access to the NASS data forms and photographic slides of the damaged vehicles is maintained by NCSA for those who need additional detail.

Half the front-outboard occupants were in bucket seats with a folding back (Table 3). The main types of seats identified were:

19 percent in bucket seats without a folding back,
50 percent in bucket seats with a folding back,
21 percent in bench seats without a folding back,
9 percent in bench seats with a folding back, and
1 percent in other types of seats (including pedestal seats).

The overall risk of seat damage in towaway crashes did not differ greatly by seat type. Seats were damaged for:

9 percent of occupants in bucket seats without a folding back,
10 percent of occupants in bucket seats with a folding back,
II percent of occupants in bench seats without a folding back,
10 percent of occupants in bench seats with a folding back, and
9 percent of occupants in other types of seats.

All types of seats were about as likely to be damaged, so the data are not separated by seat type for most of this report.

Table 3: Seat Type and Seat Performance
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Seat Type	Seat Performance	Actual Cases	Weighted Number	Percent Damaged
Bucket, not folding	No damage	3,084	1,167,242	
Bucket, not folding	Damaged	649	115,138	9%
Bucket, not folding	Unknown	48	28,936	
Bucket, not folding	Total	3,781	1,311,316	
Bucket, folding	No damage	7,624	3,145,765	
Bucket, folding	Damaged	1,784	351,493	10%
Bucket, folding	Unknown	152	61,722	
Bucket, folding	Total	9,560	3,558,980	
Bench, not folding	No damage	3,541	1,321,215	
Bench, not folding	Damaged	820	170,144	11%
Bench, not folding	Unknown	52	19,632	
Bench, not folding	Total	4,413	1,510,991	
Bench, folding	No damage	1,404	575,997	
Bench, folding	Damaged	327	65,098	10%
Bench, folding	Unknown	24	5,315	
Bench, folding	Total	1,755	646,410	
Other type	No damage	40	35,291	
Other type	Damaged	17	3,514	9%
Other type	Unknown	0	0	
Other type	Total	57	39,805	
Unknown	No damage	1	554	
Unknown	Damaged	1	13	
Unknown	Unknown	138	64,134	
Unknown	Total	140	64,701	
Total	Total	19,706	7,132,203	

The frequency of seat damage differed greatly by crash type (Table 4). Occupied seats in towaway crashes were damaged in:

- 9 percent of rollovers,
- 5 percent of nonrollover frontal impacts,
- 19 percent of nonrollover near-side impacts,
- 7 percent of nonrollover far-side impacts,
- 38 percent of nonrollover rear impacts, and
- 1 percent of other nonrollover crashes (those involving top and undercarriage damage).

More than a third of seats occupied in cars towed from a rear impact were damaged -- a substantially higher risk than for any other impact type. These data also indicate that a third (32 percent) of damaged seats with known impact type were involved in rear impacts, a quarter (27 percent) were in near-side impacts, and a quarter (26 percent) were in frontal impacts. Far-side impacts (nine percent), rollovers (six percent), and other impacts (0.1 percent) accounted for smaller numbers of damaged seats. The rest of this report is based on vehicles with one of the five primary known impact types (rollover, front, near-side, far-side, and rear).

Table 4: Impact Type and Seat Performance
(1988-1990 NASS Front-Outboard Seats of Inspected Toved Cars)

Impact Type	Seat Performance	Actual Cases	Weighted Number	Percent Damaged
Rollover	No damage	1.364	452,287	
Rollover	Damaged	344	42,915	9%
Rollover	Unknown	41	8,530	
Rollover	Total	1,749	503,732	
Front	No damage	8,461	3,135,410	
Front	Damaged	1,201	174,728	5%
Front	Unknown	171	71,712	
Front	Total	9,833	3,381,851	
Near-side	No damage	1,690	810,737	
Near-side	Damaged	966	184,984	19%
Near-side	Unknown	31	11,309	
Near-side	Total	2,687	1,007,030	
Far-side	No damage	2,066	032,043	
Far-side	Damaged	338	63,538	7%
Far-side	Unknown	36	17,089	
Far-side	Total	2,440	912,670	
Rear	No damage	739	359,292	
Rear	Damaged	610	217,075	38%
Rear	Unknown	24	23,062	
Rear	Total	1,373	599,430	
Other	No damage	88	52,704	
Other	Damaged	5	348	1%
Other	Unknown	4	6,040	
Other	Total	97	59,171	
Unknown	No damage	1.286	604,511	
Unknown	Damaged	134	21,812	3%
Unknown	Unknown	107	41,997	
Unknown	Total	1,527	668,320	
Total	Total	19,706	7,132,203	

Vehicle size was defined from curb weight, as minicompact-subcompact (up to 2,449 pounds), compact (2,450 to 2,949 pounds), intermediate (2,950 to 3,449 pounds), and fullsize-largest (over 3,449 pounds). Vehicle age was defined as calendar year minus model year. The risk of seat damage did not seem to differ greatly by vehicle curb weight within categories of towaway impact type (Table 5); for example, there was no clear pattern of greater risk of seat damage for lighter cars. Seat damage did appear more frequent in older vehicles, especially in front and rear impacts (Table 6).

	Percent of Seats Damaged in Crash	
Vehicle Age in Years	Front Impacts	Rear Impacts
Under 2 years old	3%	29%
Two to three years	4%	36%
Four to six years	5%	33%
Seven to ten years	6%	43%
Eleven years and more	8%	55%

These data represent only three calendar years of crash experience, making it difficult to separate the effects of vehicle age from the effects of design changes over the model years represented by these data. It is also possible that the older cars included here crashed at higher speeds, and that the differences in seat damage reflect differences in vehicle use.

The likelihood of seat damage appeared greater for heavier people when they were unbelted occupants in rear impacts, belted occupants in rear impacts, and unbelted occupants in frontal impacts (Table 7, based on occupants whose seat performance -- whether the seat was damaged -- was known). Belted occupants include those using any safety belt or child safety seat, but do not include those protected by an airbag alone. The estimates are summarized below,

	Percent of Seats Damaged in Crash			
Weight in	Unbelted Occupants		belted Occupants	
Pounds	Frontal	Rear	Frontal	Rear
Up to 125	6%	24%	3%	30%
126-175	9%	52%	5%	35%
Over 175	9%	48%	3%	45%

Among unbelted occupants in rear impacts, the estimated risk of seat damage was twice as high for those who weighed more than 125 pounds as it was for lighter occupants. The estimated risk of seat damage was half again as high among the heaviest occupants (those over 175 pounds) as among the lightest occupants (those up to 125 pounds) for those who were belted in rear impacts and those who were unbelted in frontal impacts, The estimated likelihood of seat damage for belted occupants in frontal impacts did not vary with occupant weight in the same way, and both the lightest and the heaviest occupants had about the same proportion of damaged seats (about three percent, compared to five percent for the middle weight group).

A description of the seat damage is available on the NASS computer file beginning in 1990. The 1990 data (presented later in this report) indicate that the type of seat damage varied with impact type. Most seat damage in rear impacts was caused by occupant loading of the seat, which would make occupant weight and belt use important factors in this crash type. However, the automated NASS data do not indicate whether the seat was loaded from the front (by the occupant of that seat) or from the rear (by another occupant).

Table 5: Impact Type, Vehicle Size, and Seat Performance
(1988-1990 NASS Front-Outboard Seats of Inspected Toved Cars)

Impact Type	Vehicle Size (Curb Weight)	Seat Performance	Actual Cases	Weighted Number	Percent Damaged
Rollover	Mini/Subcompact	No damage	695	244,513	
Rollover	Mini/Subcompact	Damaged	147	23,225	9%
Rollover	Compact	No damage	334	93,055	
Rollover	Compact	Damaged	97	0,545	8%
Rollover	Intermediate	No damage	225	83,889	
Rollover	Intermediate	Damaged	64	8,283	9%
Rollover	Fullsize/Largest	No damage	107	29,034	
Rollover	Fullsize/Largest	Damaged	36	2,862	9%
Rollover	Unknovn	No damage	3	196	
Rollover	Unknovn	Damage	0	0	
Front	Mini/Subcompact	No damage	2,907	1,145,501	
Front	Mini/Subcompact	Damaged	412	52,839	4%
Front	Compact	No damage	2,198	780,180	
Front	Compact	Damaged	325	48,788	6%
Front	Intermediate	No damage	1,762	673,517	
Front	Intermediate	Damaged	242	30,809	4%
Front	Fullsize/Largest	No damage	1,499	533,986	
Front	Fullsize/Largest	Damaged	221	42.155	7%
Front	Unknown	No damage	15	2,221	
Front	Unknown	Damage	1	138	
Near -side	Mini/Subcompact	No damage	605	268,481	
Near-side	Mini/Subcompact	Damaged	359	63,089	19%
Near-side	Compact	No damage	441	234,207	
Near-side	Compact	Damaged	259	59,116	20%
Near -side	Intermediate	No damage	330	162,999	
Near-side	Intemediate	Damaged	194	35,667	18%
Near-side	Fullsize/Largest	No damage	313	145,000	
Near-side	Fullsize/Largest	Damaged	153	26,540	15%
Near-side	Unknown	No damage	1	49	
Near-side	Unknown	Damage	1	571	
Far-side	Mini/Subcompact	No damage	720	259,980	
Far-side	Mini/Subcompact	Damaged	108	17,794	6%
Far-side	Compact	No damage	546	234,530	
Par-side	Compact	Damaged	101	12,537	5%
Far-side	Intermediate	No damage	431	199,608	
Far-side	Intermediate	Damaged	71	13,141	6%
Far-side	Fullsize/Largest	No damage	367	137,672	
Far -side	Fullsize/Largest	Damaged	57	19,916	13%
Far-side	Unknovn	No damage	2	173	
Far-side	Unknovn	Damage	1	150	
Rear	Mini/Subcompact	No damage	290	139,295	
Rear	Mini/Subcompact	Damaged	228	82,935	37%
Rear	Compact	No damage	186	102,429	
Rear	Compact	Damaged	163	60,451.	37%
Rear	Intenediate	No damage	139	62,000	
Rear	Intermediate	Damaged	122	41.533	40%
Rear	Fullsize/Largest	So damage	123	55, jj7	
Rear	Fullsize/Largest	Damaged	96	32,144	37%
Rear	Unknown	No damage	1	10	
Rear	Unknown	Damage	1	10	

Table 6: Impact Type, Vehicle Age, and Seat Performance
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Impact Type	Vehicle Age (Years)	Seat Performance	Actual Cases	Weighted Number	Percent Damaged
Rollover	Under 2	No damage	311	71,466	
Rollover	Under 2	Damaged	63	7,893	10%
Rollover	2 to 3	No damage	263	86,858	
Rollover	2 to 3	Damaged	48	7,668	8%
Rollover	4 to 6	No damage	298	116,901	
Rollover	4 to 6	Damaged	83	9,540	8%
Rollover	7 to 10	No damage	277	109,346	
Rollover	7 to 10	Damaged	89	11,037	9%
Rollover	11 plus	No damage	215	67,716	
Rollover	11 plus	Damaged	61	6,777	9%
Front	Under 2	No damage	1,548	479,289	
Front	Under 2	Damaged	170	14,235	3%
Front	2 to 3	No damage	1,708	577,837	
Front	2 to 3	Damaged	175	21,910	4%
Front	4 to 6	No damage	1,789	693,459	
Front	4 to 6	Damaged	249	33,643	5%
Front	7 to lb'	No damage	1,823	809,225	
Front	7 to 10	Damaged	343	55,449	6%
Front	11 plus	No damage	1,393	~73,600	
Front	11 plus	Damaged	264	49.491	3%
Near-side	Under 2	No damage	291	~26,600	
Near-side	Under 2	Damaged	174	24,913	16%
Near-side	2 to 3	No damage	366	188,957	
Near-side	2 to 3	Damaged	190	25,218	12%
Near-side	4 to 6	No damage	423	203,421	
Wear-side	4 to 6	Damaged	228	44,853	18%
Near-side	7 to 10	No damage	330	157,804	
Near-side	7 to 10	Damaged	229	36,293	19%
Near-side	11 plus	No damage	280	133,956	
Near-side	11 plus	Damaged	143	33,705	29%
Far-side	Undtr 2	No damage	349	125,824	
Far-side	Under 2	Damaged	50	6,352	3%
Far-side	2 to 3	No damage	422	184,366	
Far-side	2 to 3	Damaged	77	10,696	3%
Far-side	4 to 6'	No damage	508	192,565	
Far-side	4 to 6	Damaged	71	10,018	5%
Far-side	7 to 10	No damage	423	179,047	
Far-side	7 to 10	Damaged	81	13,256	7%
Far-ride	11 plus	No damage	362	150,240	
Far-side	11 plus	Damaged	39	23,217	13%
		No damage		69,432	
Rear	Under 2	Damaged	193	27,853	29%
Rear	2 to 3	No damage	14%	56,193	
Rear	2 to 3	Damaged	116	31,464	"'36%
Rear	4 to 6	No damage	205	130,408	
Rear	4 to 6	Damaged	163	63,498	33%
Rear	7 to 10	No damage	134	66,512	
Rear	7 to 10	Damaged	125	49,427	43%
Rear	11 plus	No damage	85	36,833	
Rear	11 plus	Damaged	113	44,833	55%

Table 7: Occupant Weight and Seat Performance in Frontal and Rear Impacts
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Impact Type	Belt Use	Weight in Pounds	Seat Performance	Actual Cases	Weighted Number	Percent Damaged
Front	No	Up to 125	No damage	652	202,714	
Front	No	Up to 125	Damage	99	11,881	6%
Front	No	126-175	No damage	1,468	418,932	
Front	No	126-175	Damage	306	42,429	9%
Front	No	Over 175	No damage	716	224,093	
Front	No	Over 175	Damage	169	21,653	9%
Front	No	Unknown	No damage	926	298,208	
Front	No	Unknown	Damage	207	27,380	
Front	No	Total	No damage	3,762	1,143,946	
Front	No	Total	Damage	781	103,354	0%
Front	Yes	up to 125	No damage	959	443,963	
Front	Yes	Up to 125	Damage	87	12,371	3%
Front	Yes	126-175	No damage	1,894	701,748	
Front	Yes	126-173	Damage	162	37,043	5%
Front	Yes	Over 175	No damage	937	404,441	
Front	Yes	Over 175	Damage	71	10,799	3%
Front	Yes	Unknown	No damage	780	310,109	
Front	Yes	Unknown	Damage	a7	8,803	
Front	Yes	Total	No damage	4,570	1,940,262	
Front	Yes	Total	Damage	407	69,816	3%
Rear	No	up to 125	No damage	34	19,560	
Rear	No	Up to 125	Damage	17	6,220	24%
Rear	No	126-175	No damage	66	21,831	
Rear	No	126-175	Damage	62	23,321	52%
Rear	No	Over 175	No damage	29	14,693	
Rear	No	Over 175	Damage	39	13,769	48%
Rear	No	Unknown	No damage	35	19,254	
Rear	No	Unknown	Damage	47	16,678	
Rear	No	Total	No damage	164	75,337	
Rear	No	Total	Damage	165	59,988	44%
Rear	Yes	up to 125	No damage	136	59,906	
Rear	Yes	up to 125	Damage	37	25,095	30%
Rear	Yes	126-175	No damage	236	113,896	
Rear	Yes	126-175	Damage	173	60,390	33%
Rear	Yes	Over 175	No damage	87	54,067	
Rear	Yes	Over 175	Damage	129	43,538	45%
Rear	Yes	Unknown	No damage	102	51,319"	
Rear	Yes	Unknown	Damage	77	25,510	
Rear	Yes	Total	No damage	561	279,188	
Rear	Yes	Total	Damage	436	154 754	36%

Injury Frequency *by Seat* Damage

An estimated nine percent of occupants in undamaged seats in towaway crashes of known impact type were at least moderately injured. The weighted data for the three years of NASS used here indicate an estimated:

393,479 injured at AIS 2 and
110,888 injured at AIS 3-6 or killed, among a total of
5,589,769 involved in undamaged seats

from 1988 to 1990. In contrast, an estimated 26 percent of those in damaged Seats in towaway crashes of known impact type were at least moderately injured. From 1988 to 1990, there were an estimated:

88,277 injured at AIS 2 and
88,589 injured at AIS 3-6 or killed, among a total of
683,241 involved in damaged seats

based on the NASS weighted data (unadjusted for missing impact type and seat damage data). Injury risk varied by impact type, but occupants of damaged seats were injured more frequently than were occupants of undamaged seats within each impact type (Table 8). The higher injury risk in damaged seats may reflect (at least in part) the greater impact forces in the crashes in which seats were damaged. Vehicle crash severity is considered later in this report.

The risks of moderate-to-maximum injury (the *moderate injury rate,* calculated as injuries per involved occupant) and serious-to-maximum injury (the serious *injury* rate) were higher in damaged seats and varied by vehicle impact type, as follows.

	Moderate Injury Rate		Serious Injury Rate	
	No Seat Damage	Damaged Seat	No Seat Damage	Damaged Seat
Rollover	17 percent	49 percent	5 percent	22 percent
Front	9 percent	34 percent	2 percent	16 percent
Near-side	7 percent	38 percent	1 percent	21 percent
Far-side	8 percent	23 percent	1 percent	13 percent
Rear	3 percent	5 percent	1 percent	1 percent

Occupied seats were more to be damaged in near-side than in far-side crashes (Table 4), and the injury risk in damaged seats was higher in near-side than in far-side crashes (Table 8). These data do not suggest whether seat damage increased injury (for example, by providing less protection than if the Seat had been undamaged) or decreased injury (for example, by absorbing crash forces), and it may not be possible to draw such conclusions from the automated data. One complication is the relationship between seat damage and crash severity, which is explored later in this report,

Table 8: Impact Type, Seat Performance, and Injury Severity
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Impact Type	Seat Performance	Injury Severity	Actual Cases	Weighted Number	
Rollover	No damage	Uninjured	182	149,992	33%
Rollover	No damage	AIS 1	690	225,387	50%
Rollover	No damage	AIS 2	253	54,581	12%
Rollover	No damage	AIS 3-6	239	22,327	5%
Rollover	No damage	Total	1,364	452,287	100%
Rollover	Damaged	Uninjured		2,014	5%
Rollover	Damaged	AIS 1	[illegible]	20,083	47%
Rollover	Damaged	AIS 2	68	11,177	26%
Rollover	Damaged	AIS 3-6	154	9,641	22%
Rollover	Damaged	Total	344	42,915	100%
Front	No damage	Uninjured	2,136	1,512,842	48%
Front	No damage	AIS 1	4,436	1,324,793	42%
Front	No damage	AIS 2	1,245	234,329	7%
Front	No damage	AIS 3-6	644	63,446	2%
Front	No damage	Total	8,461	3,135,410	100%
Front	Damaged	Uninjured	78	32,370	19%
Front	Damaged	AIS 1	477	83,690	48%
Front	Damaged	AIS 2	220	30,158	17%
Front	Damaged	AIS 3-6	426	28,510	16%
Front	Damaged	Total	1,201	174,728	100%
Near-side	No damage	Uninjured	472	390,375	48%
Near-side	No damage	AIS 1	895	366,882	45%
Near-side	No damage	AIS 2	223	41,853	5%
Near-side	No damage	AIS 3-6	100	11,628	1%
Near-side		Total	1,690	810,737	100%
Near-side	Damaged	Uninjured	47	23,579	13%
Near-side	Damaged	AIS 1	337	90,239	49%
Near-side	Damaged	AIS 2	192	31,639	17%
Near-side	Damaged	AIS 3-6	390	39,526	21%
Near-side	Damaged	Total	966	184,984	100%
Far-side	No damage		640	410,472	49%
Far-side	No damage	Uninjured	1,034	356,441	43%
Far-side	No damage	AIS 2	251	53,614	6%
Far-side	No damage	AIS 3-6	141	11,516	1%
	No damage	Total	2,066	832,043	100%
Far-side	Damaged	Uninjured	29	9,224	15%
Far-side	Damaged	AIS 1	134	39,974	63%
Far-side	Damaged	AIS 2	53	5,932	9%
Far-side	Damaged	AIS 3-6	122	8,409	13%
Far-side	Damaged	Total	338	63,538	100%
Rear	No damage	Uninjured	243	182,200	51%
Rear	No damage	AIS 1	441	166,019	46%
Rear	No damage	AIS 2	42	9,103	3%
Rear	No damage	AIS 3-6	13	1,971	1%
Rear	No damage	Total	739	359,292	100%
Rear	Damaged	Uninjured	123	55,927	26%
Rear	Damaged	AIS 1	404	149,275	69%
Rear	Damaged	AIS 2	52	9,372	4%
Rear	Damaged	AIS 3-6	31	2,502	1%
	Damaged	Total	610	217,075	100%

Moderate injury appears more likely for occupants in damaged (compared to undamaged) seats in rollovers (Table 9), frontal impacts (Table 10), near-side impacts (Table 11), and far-side impacts (Table 12) -- for both belted and unbelted occupants= This means, for example, that risk of injury among unbelted occupants in frontal impacts was greater in damaged than in undamaged seats. The effect is not as clear in rear impacts (Table 13), possibly because there are so few moderate injuries in 'rear impacts; the effect for all injuries in rear impacts (minor and more severe] does appear to follow the pattern shown in the other three damage types.

It is not clear why belt use was less frequent in damaged. seats, but estimates derived from these four tables indicate this was the case. The frequency of belt use (belt users per involved occupant, calculated from occupants with known data), is estimated as follows,

	Belt Use Rate		
	No Seat Damage	Damaged Seat	Overall
Rollover	59 percent	39 percent	57 percent
Front	63 percent	40 percent	62 percent
Near-side	72 percent	50 percent	68 percent
Far- side	72 percent	41 percent	69 percent
Rear	79 percent	72 percent	76 percent

Previous research has shown that belt users tend to be involved in crashes at lower speeds (*Final Regulatory* Impact *Analysis: Amendment to* Federal *Motor Vehicle* Safety *Standard 208*, Passenger Car Front Seat *Occupant Protection*, NHTSA, DOT-HS-806-572, July 1984), so more-frequent belt use in undamaged seats may partly reflect the lower crash forces associated with belt use. The association between crash severity and belt use is frequently attributed to differences in driver attitudes toward risk, which are reflected in a tendency for drivers who speed or drink (or otherwise put themselves at increased risk of collision) to also neglect to use an available safety belt. This tendency may also explain why belt use is lower in rollover and frontal impacts than in side and rear collisions. Useful comparisons of injury risk and injury type by seat performance will need to account for differences in belt use by seat performance and for differences in injury risk by impact type and belt use.

Ejection is rare among belted occupants, so only unbelted occupants were used to compare the likelihood of ejection from.damaged and undamaged seats. Unbelted occupants of seats damaged in a rollover, frontal impact, near-side, or far-side impact were more likely to be completely or partially ejected than were unbelted occupants of undamaged seats (Table 14). The degree of ejection (whether complete or partial) was unknown for a small number of occupants who were known to be ejected; these are labeled *Unk Deg* in the table. Ejections of unknown degree have been prorated between complete ejections and partial ejections in calculating the percentages shown in Table 14. In large part, the differences in ejection risk reflect differences in crash severity -- severe crashes were more likely to result in seat damage and to involve occupant ejection and injury, There were very few ejections from cars with damage to the rear, but the available data do not suggest that occupants in damaged seats were more likely to be ejected than were occupants in undamaged seats.

Table 9: Seat Performance, Belt Use, and Injury Severity in Rollovers
(1988-1990 NASS Front-Outboard Seats of Inspected Toved Cars)

Seat Performance	Belt Used	Injury Severity	Actual Cases	Weighted Numb	
No damage	No	Uninjured	56	28,537	18
No damage	No	AIS 1	[illegible]	104,799	56%
No damage	No	AIS 2	153	34,939	19%
No damage	No	AIS 3-6	182	16,649	9%
No damage		Total	721	182,924	100%
No damage	Yes	Uninjured	119	112,058	43%
No damage	Yes	AIS 1	351	121,448	47%
No damage	Yes	AIS 2	100	19,642	8%
No damage	Yes	AIS 3-6	55	5,345	2%
No damage	Yes	Total	625	258,493	100%
No damage	Unknown	Total	18	10,870	
Damaged	No	Uninjured	2	710	3%
Damaged	No	AIS 1	60	10,558	41%
Damaged	No	AIS 2	40	6,631	26%
Damaged	No	AIS 3-6	116	7,945	31%
Damaged	No	Total	218	25,844	100%
Damaged	Yes	Uninjured	9	1,304	8%
Damaged	Yes	AIS 1	48	9,397	56%
Damaged	Yes	AIS 2	28	4,546	27%
Damaged	Yes	AIS 3-6	33	1,402	8%
Damaged	Yes	Total	118	16,649	100%
Damaged	Unknown	Total	8	422	

Table 10: Seat Performance, Belt Use, and Injury Severity in Frontal Impacts
(1988-1990 NMS Front-Outboard Seats of Inspected Toved Cars)

Seat Performance	Belt Used	Injury Severity	Actual Cases	Weighted Number	
No damage	No	Uninjured	562	402,243	35%
No damage	No	AIS 1	2,060	572,826	50%
No damage	No	AIS 2	733	129,769	11%
No damage	No	AIS 3-6	407	39,109	3%
No damage	No	Total	3,762	1,143,946	100%
No damage	Yes	Uninjured	1,512	1,072,644	55%
No damage	Yes	AIS 1	2,327	740,294	38%
No damage	Yes	AIS 2	504	103,491	5%
No damage	Yes	AIS 3-6	227	23,832	1%
No damage	Yes	Total	4,570	1,940,262	100%
No damage	Unknown	Total	129	51,202	
Damaged	No	Uninjured	37	8,124	8%
Damaged	No	AIS 1	300	54,636	53%
Damaged	No	AIS 2	148	20,315	20%
Damaged	No	AIS 3-6	296	20,278	20%
Damaged	No	Total	781	103,354	100%
Damaged	Yes	Uninjured	39	23,390	34%
Damaged	Yes	AIS 1	174	28,718	41%
Damaged	YES	AIS 2	71	9,836	14%
Damaged	Yes	AIS 3-6	123	7,872	11%
Damaged	Yes	Total	407	69,816	100%
Damaged	Unknown	Total	13	1,558	

Table 11: Seat **Performance, Belt Use,** and Injury Severity in Near-Side Impacts
(1988-1990 NASS Front-Outboard Seats of Inspected **Towed** Cars)

Seat Performance	Belt Used	Injury Severity	Actual Cases	Weighted Number	
No damage	No	Uninjured	106	88,800	40%
No damage	No	AIS 1	298	110,172	49%
No damage	No	AIS 2	102	17,267	8%
No damage	No	AIS 3-6	51	7,028	3%
No damage	No	Total	557	223,267	100%
No damage	Yes	Uninjured	353	291,691	52%
No damage	Yes	AIS 1	579	245,277	43%
No damage	Yes	AIS 2	119	24,465	4%
No damage	Yes	AIS 3-6	47	4,551	1%
No damage	Yes	Total	1,098	565,983	100%
No damage	Unknown	Total	35	21,487	
Damaged	No	Uninjured	19	6,247	3%
Damaged	No		167	55,231	62%
Damaged	No	AIS 2	98	12,844	14%
Damaged	No	AIS 3-6	205	15,441	17%
Damaged	No	Total	489	89,763	100%
Damaged	Yes	Uninjured	26	15,894	17%
Damaged	Yes	AIS 1	163	33,105	36%
Damaged	Yes	AIS 2	90	18,131	20%
Damaged	Yes	AIS 3-6	184	24,075	26%
Damaged	Yes	Total	463	91,205	100%
Damaged	Unknown	Total	14	4,016	

Table 12: Seat **Performance,** Belt Use, and Injury Severity in Par-Side Impacts
(1988-1990 NASS Front-Outboard Seats of **Inspected Towed** Cars)

Seat Performance	Belt Used	Injury Severity	Actual Cases	Weighted Number	
No damage	No	Uninjured	168	8[illegible],018	37%
No damage	No	AIS 1	394	112,205	49%
No damage	No	AIS 2	139	25,893	11%
No damage	No	AIS 3-6	101	7,918	3%
No damage	No	Total	802	231,034	100%
No damage	Yes	Uninjured	459	315,142	54%
No damage	Yes	AIS 1	627	237,332	41%
No damage	Yes	AIS 2	110	27,482	5%
No damage	Yes	AIS 3-6	38	3,567	1%
No damage	Yes	Total	1,234	583,523	100%
No damage	Unknown	Total	30	17,485	
Damaged	No	Uninjured	10	3,103	8%
Damaged	No		68		67%
Damaged	No	AIS 2	30	[illegible]	10%
Damaged	No	AIS 3-6	79	5,659	15%
Damaged	No	Total	187	37,478	100%
Damaged	Yes	Uninjured	1%	5,829	23%
Damaged	Yes	AIS 1	66	15,000	59%
Damaged	Yes	AIS 2	23	2,189	9%
Damaged	Yes	AIS 3-6	41	2,605	10%
Damaged	Yes	Total	148	25,624	100%
Damaged	Unknown	Total	3	437	

Table 13: Seat Performance, Belt Use, and Injury Severity in Rear Impacts (1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Seat Performance	Belt Used	Injury Severity	Actual Cases	Weighted Number	
No damage	No	Uninjured	49	40,841	54%
No damage	No	AIS 1	96	29,465	39%
No damage	No	AIS 2	15	4,476	6%
No damage	No	AIS 3-6	4	555	1%
No damage	No	Total	164	75,337	100%
No damage	Yes	Uninjured	187	138,801	50%
No damage	Yes	AIS 1	338	134,344	48%
No damage	Yes	AIS 2	27	4,627	2%
No damage	Yes	AIS 3-6	9	1,416	1%
No damage	Yes	Total	561	279,188	100%
No damage	Unknovn	Total	14	4,767	
Damaged	No	Uninjured	42	20,924	35%
Damaged	No	AIS 1	90	35,825	60%
Damaged	No	AIS 2	15	1,971	3%
Damaged	No	AIS 3-6	18	1,267	2%
Damaged	No	Total	165	59,988	100%
Damaged	Yes	Uninjured	79	34,173	22%
Damaged	Yes	AIS 1	310	112,427	73%
Damaged	Yes	AIS 2	36	6,346	4%
Damaged	Yes	AIS 3-6	11	1,207	1%
Damaged	Yes	Total	436	154,754	100%
Damaged	Unknovn	Total	9	2,334	

Table 14: Impact Type, Seat Performance, and Ejection for Unbelted Occupants (1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Impact Type	Seat Performance	Ejection Status	Actual Cases	Weighted Number	
Rollover	No damage	None	476	148,514	82.6%
Rollover	No damage	Complete	167	23,292	13.1%
Rollover	No damage	Partial	52	7,606	4.3%
Rollover	No damage	Unk deg	6	429	
Rollover	No damage	Unknown	20	3,082	
Rollover	No damage	Total	721	182,924	100.0%
Rollover	Damaged	None	131	16,601	65.2%
Rollover	Damaged	Complete	61	6,697	26.7%
Rollover	Damaged	Partial	19	2,039	8.1%
Rollover	Damaged	Unk deg	5	144	
Rollover	Damaged	Unknown	2	362	
Rollover	Damaged	Total	218	25,844	100.0%
Front	No damage	None	3,683	1,131,866	99.1%
Front	No damage	Complete	19	3,292	0.3%
Front	No damage	Partial	52	7,319	0.6%
Front	No damage	Unk deg	1	128	
Front	No damage	Unknown	7	1,342	
Front	No damage	Total	3,762	1,143,946	100.0%
Front	Damaged	None	726	98,255	95.5%
Front	Damaged	Complete	14	932	0.9%
Front	Damaged	Partial	33	3,623	3.6%
Front	Damaged	Unk deg	1	127	
Front	Damaged	Unknown	7	416	
Front	Damaged	Total	781	103,354	100.0%
Near-side	No damage	None	518	217,450	97.4%
Near-side	No damage	Complete	28	3,800	1.9%
sear-side	No damage	Partial	8	1,336	0.7%
Near-side	No damage	Unk deg	3	681	
Near-side	No damage	Unknown	0	0	
Near-side	No damage	Total	557	223,267	100.0%
Near-side	Damaged	None	418	80,710	90.9%
Near-side	Damaged	Complete	27	1,762	2.0%
Wear-side	Damaged	Partial	35	6,300	7.1%
Near-side	Damaged	Unk deg	2	38	
Near-si	Damaged	Unknown	7	953	
Near-side	Damaged	Total	489	89,763	100.0%
Far-sidt	No damage	None	771	227,267	98.7%
Far -side	No damage	Complete	19	2,082	0.9%
Far-side	No damage	Partial	9	917	0.4%
Far -side	No damage	Unk deg	0	0	
Far-side	No damage	Unknown	3	768	
Far-side	No damage	Total	802	231,034	100.0%
Far-side	Damaged	None	162	33,412	92.8%
Far-side	Damaged	Complete	17	943	2.6%
far-side	Damaged	Partial	5	1,622	4.5%
Far-sidt	Damaged	Unk deg	2	24	
Far-side	Damaged	Unknown	1	1,477	
Far-side	Damaged	Total	187	37,478	100.0%
Rear	No damage	None	157	74,178	98.9%
Rear	No damage	Complete	6	856	1.1%
Rear	No damage	Partial	0	0	0.0%
Rear	No damage	Unk deg	0	0	
Rear	No damage	Unknown	1	303	
Rear	No damage	Total	164	75,337	100.0%
Rear	Damaged	None	160	59,846	43.6%
Rear	Damaged	Complete	5	141	0.2%
Rear	Damaged	Partial	0	0	0.0%
Rear	Damaged	Unk deg	0	0	
Rear	Damaged	Unknown	0	0	
Rear	Damaged	Total	165	59,988	100.0%

Injury Type by Seat Damage

Tables 15, 17, 19, 21, and 23 describe injured body areas, by vehicle impact type. The tables describe all identified injuries of at least moderate severity, including multiple injuries to the same person. Injuries were not identified for many fatalities (including those. who died before treatment and were not autopsied), but no attempt has been made here to adjust the estimates for missing injury data. The head and neck accounted for the largest number of moderate and more severe injuries to occupants of undamaged seats, for most categories of belt use and vehicle damage. Torso injuries were a larger fraction of moderate and more severe injuries among occupants of damaged seats, but some of this difference may reflect differences in crash severity and impact configuration. The tables also show injured body areas for serious and more severe injury, a subset of the moderate and more severe injuries. The torso accounted for the largest number of serious and more severe injuries for most categories of seat performance, belt use, and vehicle damage.

NASS investigators were able to identify injury sources for four-fifths of the documented moderate and more severe injuries. Seatbacks caused no more than eight percent of these injuries in rollover crashes (Table 16), frontal impacts (Table 18), near-side impacts (Table 20), and far-side impacts (Table 22), based on the known injury contact data. This was the case for belted and for unbelted occupants, in damaged and undamaged seats. A larger fraction of moderate and more severe injuries in rear impacts were caused by contacting the seatback (Table 24):

13 percent for those unbelted in undamaged seats,
6 percent for those belted in undamaged seats,
26 percent for those unbelted in damaged seats, and
24 percent for those belted in damaged seats.

In rear impacts, it appears that occupants of damaged seats received more of their injuries from seatback contact than did occupants of undamaged seats. In some cases, heavy occupant loading of the seatback may have caused both seat damage and occupant injury; the data do not indicate whether seat damage exacerbated injury. About 73 percent of the injuries in seats undamaged in rear impacts were attributed to frontal components. However, some rear impacts included secondary impacts to the front or side (either before or after the rear impact), and some injuries from frontal components in these crashes may not have occurred during the rear impact itself: the data do not indicate whether occupants rebounded or rotated into front structures after rear impact.

There were very few moderate and more severe injuries caused by a contact identified (from the automated data alone) as behind a normally-seated front-outboard occupant. Injury contacts known to be behind a front-seated occupant include the rear header, backlight area, and pillars rearward of the B-pillar. Most identified injury sources that could be classified as front or rear components were front components (such as the windshield area, instrument panel, and front floor area), However, many identified injury sources extended both forward and rearward of the occupant; for example, roof and side rail injury contacts are not identified in further detail in the automated data; the B-pillar was also classified as an ambiguous source. A review cf the completed NASS data collection forms (including the sketch of the vehicle interior and suspected contact points) and photographs of the vehicle might identify the relative position for some of these contacts.

Table 15: Body Regions of Moderate and More Severe Injuries in Rollovers
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

			Moderate and More Severe			Serious and More Severe		
Seat Performance	Belt Use	Injured Body Region	Actual Cases	Weighted Data		Actual Cases	Weighted Data	
No damage	No	Head-neck	361	36,626	41%	169	11,429	42%
No damage	No	Torso	299	29,941	34%	139	11,129	41%
No damage	No	Arm	68	13,818	16%	20	1,535	6%
No damage	No	Leg	76	8,160	9%	34	3,196	12%
No damage	No	Unknown	1	10		1	10	
No damage	No	Total	805	88,555	100%	363	27,300	100%
No damage	Yes	Head-neck	125	16,088	42%	36	2,243	33%
No damage	Yes	Torso	71	10,299	27%	24	1,918	28%
No damage	Yes	Arm	47	7,810	20%	10	1,991	29%
No damage	Yes	Leg	22	4,342	11%	7	644	9%
No damage	Yes	Unknown	1	37		0	0	
No damage	Yes	Total	266	38,575	100%	77	6,796	100%
Damaged	No	Head-neck	201	17,162	37%	96	8,160	36%
Damaged	No	Torso	219	20,776	45%	114	11,978	53%
Damaged	No	Arm	40	4,317	9%	9	560	2%
Damaged	No	Leg	59	3,968	9%	24	2,073	9%
Damaged	No	Unknown	0	0		0	0	
Damaged	No	Total	519	46,224	100%	243	22,771	100%
Damaged	Yes	Head-neck	110	7,043	33%	52	1,412	38%
Damaged	Yes	Torso	116	4,624	10%	53	1,367	42%
Damaged	Yes	Arm	21	1,449		9	362	10%
Damaged	Yes	Leg	21	1,095	8%	11	391	10%
Damaged	Yes	Unknown	0	0		0	0	
Damaged	Yes	Total	268	14,211	100%	125	3,733	100%

Table 16: Sources of Moderate and More Severe Injuries in Rollovers
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

			Moderate and More Severe		
Seat Performance	Belt Use	General Area of Injury Source	Actual Cases	Weighted Data	
No damage	No	Front component	232	26,498	40%
No damage	No	Rear component	0	0	0%
No damage	No	Seatback	9	912	1%
No damage	No	Other/unclear	283	38,099	58%
No damage	No	Unknown source	281	23,046	
No damage	No	Total	805	88,555	100%
No damage	Yes	Front component	84	11,397	38%
No damage	Yes	Rear component	0	0	0%
No damage	Yes	Seatback	4	1,540	5%
No damage	Yes	Other/unclear	98	17,367	57%
No damage	Yes	Unknown source	80	8,271	
No damage	Yes	Total	266	38,575	100%
Damaged	No	Front component	204	26,542	72%
Damaged	No	Rear component	0	0	0%
Damaged	No	Seatback	3	182	0%
Damaged	No	Other/unclear	165	10,122	27%
Damaged	No	Unknown source	147	9,377	
Damaged	No	Total	519	46,224	100%
Damaged	Yes	Front component	117	5,599	46%
Damaged	Yes	Rear component	0	0	0%
Damaged	Yes	Seatback	6	243	2%
Damaged	Yes	Other/unclear	94	6,331	52%
Damaged	Yes	Unknown source	51	2,036	
Damaged	Yes	Total	268	14,211	100%

Table 17: Body Regions of Moderate and More Severe Injuries in Frontal Impacts
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Seat Performance	Belt Use	Injured Body Region	Moderate and More Severe: Actual Cases	Moderate and More Severe: Weighted Data		Serious and More Severe: Actual Cases	Serious and More Severe: Weighted Data	
No damage	No	Head-neck	971	119,731	44%	184	13,530	22%
No damage	No	Torso	732	70,679	26%	371	29,543	48%
No damage	No	Arm	243	29,979	11%	43	3,234	5%
No damage	No	Leg	306	31,793	19%	180	14,629	24%
No damage	No	Unknown	1	133		0	0	
No damage	No	Total	2,453	272,318	100%	778	60,935	100%
				63,567	32%			
No damage	Yes	Head-neck	442	68.586	35%	88	5,278	13%
No damage	Yes	Torso		[illegible]				42%
No damage	Yes	Arm	5249	15,518	8%	129	14,851	6%
No damage	Yes	Lea	336	48,169	25%	96	12,840	31%
No damage	Yes	Unknown	0	0		0	0	
No damage	Yes	Total	1.448	195.839	100%	394	35,081	100%
Damaged	No	Head-neck	533	35,857				21%
Damaged	No	Torso	785	44,349	35% 29%	220 472	23,802 10,025	49%
Damaged	No	Arm	170	11,017	9%	38	1,756	4%
Damaged	No	Leg	396	34,155	27%	174	13,300	27%
Damaged	No	Unknown	6	535		0	0	
Damaged	No	Total	1,890	125,914	100%	904	48,884	100%
Damaged	Yes	Head-neck	209	12,941	26%	86	4,160	[illegible]
Damaged	Yes	Torso	241	16,175	32%	128	1,460	44%
Damaged	Yes	Arm	84	8,540	17%	12	849	5%
Damaged	Yes	Leg	201	12,648	25%	70	4,379	26%
Damaged	Yes	Unknown	0	0		0	0	
Damaged	Yes	Total	735	50,304	100%	296	16,848	100%

Table 18: Sources of Moderate and More Severe Injuries in Frontal Impacts
(1988-1990 NASS Front-Outboard Seats of Inspected Toved Cars)

Seat Performance	Belt Use	General Area of Injury Source	Moderate and More Severe: Actual Cases	Moderate and More Severe: Weighted Data	
No damage	No	Front component	2,014	236,387	96%
No damage	No	Rear component	0	0	0%
No damage	No	Seatback	12	1,861	1%
No damage	No	Other/unclear	66	7,445	3%
No damage	No	Unknown source	361	26,625	
No damage	No	Total	2,453	272,318	100%
No damage	Yes	Front component	991	133,123	75%
No damage	Yes	Rear component	0	0	0%
No damage	Yes	Seatback	15	2,075	1%
No damage	Yes	Other/unclear	248	41,418	23%
No damage	Yes	Unknown source	194	19,224	
No damage	Yes	Total	1,448	195,839	100%
Damaged	No	Front component	1,396	104,692	96%
Damaged	No	Rear component	4	83	0%
Damaged	No	Seatback	7	960	1%
Damaged	No	Other/unclear	77	3,606	3%
Damaged	No	Unknown source	406	16,573	
Damaged	No	Total	1,890	125,914	100%
Damaged	Yes	Front component	504	34,[illegible]	[illegible]3%
Damaged	Yes	Rear component	0	0	0%
Damaged	Yes	Seatback	13	1,793	4%
Damaged	Yes	Other/unclear	72	5,330	13%
Damaged	Yes	Unknown source	146	8,761	
Damaged	Yes	Total	735	50,304	100%

Table 19: Body Regions of Moderate and More Severe Injuries in Near-Side Impacts (1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

			Moderate and More Severe			Serious and More Severe		
Seat Performance	Belt Use	Injured Body Region	Actual Cases	Weighted Data		Actual Cases	Weighted Data	
No damage	No	Head-neck	122	16,362	41%	38	3,403	36%
No damage	No	Torso	114	16,253	40%	36	3,895	41%
No damage	No	Arm	24	2,904	7%	4	496	5%
No damage	No	Leg	24	4,859	12%	8	1,758	18%
No damage	No	Unknown	1	199		0	0	
No damage	No	Total	285	40,577	100%	86	9,551	100%
No damage	Yes	Head-neck	121	18,275	42%	24	1,424	18%
No damage	Yes	Torso	149	20,797	48%	56	5,895	74%
No damage	Yes	Arm	24	3,037	7%	1	209	3%
No damage	Yes	Leg	19	1,538	4%	7	428	5%
No damage	Yes	Unknown	1	284		0	0	
No damage	Yes	Total	314	43,931	100%	88	7,956	100%
Damaged	No	Head-neck	355	21,792	24%	184	7,806	20%
Damaged	No	Torso	721	51,241	57%	388	22,776	59%
Damaged	No	Arm	83	8,866	10%	25	4,481	12%
Damaged	No	Leg	116	7,244	8%	46	3,443	9%
Damaged	No	Unknown	0	0		0	0	
Damaged	No	Total	1,275	89,143	100%	643	38,507	100%
Damaged	Yes	Head-neck	302	32,888	30%	167	12,939	28%
Damaged	Yes	Torso	613	64,997	58%	295	26,799	57%
Damaged	Yes	Arm	45	8,501	8%	15	5,557	12%
Damaged	Yes	Leg	90	4,748	4%	37	1,669	4%
Damaged	Yes	Unknown	0	0		0	0	
Damaged	Yes	Total	1,050	111,134	100%	514	46,964	100%

Table 20: Sources of Moderate and More Severe Injuries in Near-Side Impacts (1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

			Moderate and More Severe		
Seat Performance	Belt Use	General Area of Injury Source	Actual Cases	Weighted Data	
No damage	No	Front component	176	28,709	82%
No damage	No	Rear component	0	0	0%
No damage	No	Seatback	1	15	0%
No damage	No	Other/unclear	60	6,356	18%
No damage	No	Unknown source	48	5,497	
No damage	No	Total	285	40,577	100%
No damage	Yes	Front component	193	32,695	84%
No damage	Yes	Rear component	1	103	0%
No damage	Yes	Seatback	0	0	0%
No damage	Yes	Other/unclear	63	6,276	16%
No damage	Yes	Unknown source	57	4,857	
No damage	Yes	Total	314	43,931	100%
Damaged	No	Front component	773	62,882	79%
Damaged	No	Rear component	0	0	0%
Damaged	No	Seatback	6	210	0%
Damaged	No	Other/unclear	265	16,091	20%
Damaged	No	Unknown source	231	9,960	
Damaged	No	Total	1,275	89,143	100%
Damaged	Yes	Front component	645	73,496	75%
Damaged	Yes	Rear component	4	58	0%
Damaged	Yes	Seatback	7	1,228	1%
Damaged	Yes	Other/unclear	208	22,602	23%
Damaged	Yes	Unknown source	186	13,750	
Damaged	Yes	Total	1,050	111,134	100%

Table 21: Body Regions of Moderate and More Severe Injuries in Far-Side Impacts
(1988-1990 NASS Front-Outboard Seats of Inspected Toved Cars)

			Moderate and More Severe			Serious and More Severe		
Seat Performance	Belt Use	Injured Body Region	Actual Cases	Weighted Data		Actual Cases	Weighted Data	
No damage	No	Head-neck	269	34,002	61%	97	7,195	54%
No damage	No	Torso	198	16,499	30%	99	5,585	42%
No damage	No	Arm	30	2,248	4%	7	340	3%
No damage	No	Leg	34	3,058	5%	6	279	2%
No damage	No	Unknown	0	0		0	0	
No damage	No	Total	531	55,806	100%	209	13,398	100%
No damage	Yes	Head-neck	99	15,115	35%	22	2,390	39%
No damage	Yes	Torso	118	12,366	29%	41	2,328	38%
No damage	Yes	Arm	39	9,764	23%	8	862	14%
No damage	Yes	Leg	25	5,511	13%	4	611	10%
No damage	Yes	Unknown	0	0		0	0	
No damage	Yes	Total	281	42,756	100%	75	6,191	100%
				14,932		81		
Damaged	NO	Head-neck	164	14.491	47%	106	6,097	44%
Damaged	No	Torso		[illegible]		7		48%
Damaged	No	Arm	115	727	43%	9	[illegible]	2%
Damaged	No	Leg	17	1,743	3%		879	6%
Damaged	No	Unknown	0	0		0	0	
Damaged	No	Total	375	31,893	100%	203	13,860	100%
					43%	55		
Damaged	Yes	Head-neck	103	7,375	42%	83	2,037	30%
Damaged	Yes	Torso	132	7,181			3,448	47%
Damaged	Yes	Arm	17	1,330	8%	5		
Damaged	Yes	Leg	17	1,295	8%	8	434 675	9% 6%
Damaged	Yes	Unknown	1	37		0	0	
Damaged	Yes	Total	270	17,219	100%	151	7,395	100%

Table 22: Sources of Moderate and More Severe Injuries in Far-Side Impacts
(1988-1990 NMS Front-Outboard Seats of Inspected Toved Cars)

			Moderate and More Severe		
Stat Performance	Belt Use	General Area of Injury Source	Actual Cases	Weighted Data	
No damage	No	Front component	292	33,372	75%
No damage	No	Rear component	0	0	0%
No damage	No	Seatback	7	1,375	3%
No damage	No	Other/unclear	117	9,718	22%
No damage	No	Unknown source	115	11,342	
No damage	No	Total	531	55,806	100%
No damage	Yes	Front component	104	22,270	63%
No damage	Yes	Rear component		0	0%
No damage	Yes	Strtbrck	8	1,442	4%
No damage	Yes	Other/unclear	89	11,567	33%
No damage	Yes	Unknown source	79	7,478	
No damage	Yes	Total	281	42,756	100%
	No				68%
Damaged	No	Front component	196	[illegible]	0%
Damaged	No	Rear component	12	2,310	8%
Damaged	No	Other/unclear	71	6,419	23%
Damaged	No	Unknown source	96	4,346	
Damaged	No	Total	375	31,893	100%
Damaged	Yes	Front component	94	6,611	40%
				499	4%
Damaged	Yes	Seatbackponent	95	663	5%
Damaged	Yes	Other/unclear		5,769	43%
Damaged	Yes	Unknown source	74	3,675	
Damaged	Yes	Total	270	17,219	100%

Table 23: Body Regions of Moderate and More Stvtrt Injuries in Rear Impacts
(1988-1990 NASS Front-Outboard Stats of Inspected Toved Cars)

Seat Performance	Belt Use	Injured Body Region	Moderate and More Severe Actual Cases	Moderate and More Severe Weighted Data		Serious and More Severe Actual Cases	Serious and More Severe Weighted Data	
No damage	No	Head-neck	16	2,655	35%	2	185	26%
No damage	No	Torso	11	2,538	33%	3	524	74%
No damage	No	Arm	1	145	2%	0	0	0%
No damage	No	Leg	4	2,274	30%	0	0	0%
No damage	No	Unknown	0	0		0	0	
No damage	No	Total	32	7,612	100%	5	710	100%
No damage	Yes	Head-neck	28	3,709	54%	2	120	9%
No damage	Yes	Torso	12	1,247	18%	4	192	14%
No damage	Yes	Arm	1	301	4%	0	0	0%
No damage	Yes	Leg	3	1,617	24%	2	1,090	78%
No damage	Yes	Unknown	0	0		0	0	
No damage	Yes	Total	44	6,874	100%	8	1,403	100%
Damaged	No	Head-neck	45	3,019	51%	27	910	39%
Damaged	No	Torso	56	2,188	37%	35	1,425	61%
Damaged	No	Arm	3	573	10%	0	0	0%
Damaged	No	Leg	5	131	2%	0	0	0%
Damaged	No	Unknown	1	205		1	205	
Damaged	No	Total	110	6,116	100%	63	2,540	100%
Damaged	Yes	Head-neck	47	3,491	34%	12	357	22%
Damaged	Yes	Torso	28	4,037	40%	12	1,288	78%
Damaged	Yes	Arm	3	1,788	18%	0	0	0%
Damaged	Yes	Leg	12	866	9%	2	10	1%
Damaged	Yes	Unknown	1	15		1	15	
Damaged	Yes	Total	91	10,197	100%	27	1,669	100%

Table 24: Sources of Moderate and More Stvtrt Injuries in Rear Impacts
(1988-1990 NASS Front-Outboard Scats of Inspected Toved Cars)

Seat Performance	Belt Use	General Area of Injury Source	Moderate and More Stvtrt Actual Cases	Moderate and More Stvtrt Weighted Data	
No damage	No	Front component	15	5,247	74%
No damage	No	Rear component	0	0	0%
No damage	No	Seatback	3	957	13%
No damage	No	Other/unclear	7	889	13%
No damage	No	Unknown source	7	520	
No damage	No	Total	32	7,612	100%
No damage	Yts	Front component	15	4,326	71%
No damage	Yts	Rear component	0	0	0%
No damage	Yts	Seatback	3	384	6%
No damage	Yes	Other/unclear	14	1,363	22%
No damage	Yes	Unknown source	12	802	
No damage	Yes	Total	44	6,874	100%
Damaged	No	Front component	30	1,398	29%
Damaged	No	Rear component	4	250	5%
Damaged	No	Seatback	29	1,255	26%
Damaged	No	Other/unclear	21	1,956	40%
Damaged	No	Unknown source	26	1,256	
Damaged	No	Total	110	6,116	100%
Damaged	Yes	Front component	28	1,791	30%
Damaged	Yes	Rear component	2	115	2%
Damaged	Yes	Seatback	15	1,439	24%
Damaged	Yts	Other/unclear	22	2,666	44%
Damaged	Yes	Unknown source	24	4,187	
Damaged	Yes	Total	91	10,197	100%

Many moderate and more severe injuries from frontal contacts in rear impacts involved the legs and arms (Table 25), but the injury mechanisms that cause limb injuries may differ from those that cause other injuries. A large fraction of these occupants with at least one moderate or more severe injury to the head, neck, or torso were in vehicles with multiple impacts (Table 26). Half the belted occupants with any of these head, neck, or torso injuries were cars that received frontal damage, either befdre or after the rear impact.

Table 25: Body Regions of Moderate and More Severe Injuries from Contacting Frontal Components in Rear Impacts (1988-1990 NASS Front-Outboard Stats of Inspected Toved Cars)

Stat Performance	Belt Use	Injurtd Part Region	ACtual Cases	Weighted Data	
No damage	No	Head-neck	6	1,101	21%
No damage	No	Torso	3	1.871	36%
No damage	NO	Arm	0	0	ox
No damage	No	Leg	4	2.274	43%
No damage	No	Total	15	5,247	100%
No damage	Yes	Head-neck	9	2,039	47%
No damage	Yes	Torso	3	408	9%
No damage	Yes	Arm	1	301	7%
No damage	Yes	Leg	2	1.578	36%
No damage	Yes	Total	15	4,326	100%
Damaged	No	Head-neck	3	99	7%
Damaged	No	Torso	25	1,060	76%
Damaged	No	Arm	1	181	13%
Damaged	No	Leg	1	57	4%
Damaged	No	Total	30	1,398	100%
Damaged	Yes	Head-neck	4	35%	20%
Damaged	Yes	Torso	15	635	35%
Damaged	Yes	Arm	1	249	14%
Damaged	Yes	Leg	8	548	31%
Damaged	Yes	Total	28	1,791	100%

Table 26: Secondary Vthiclt Damage for Occupants vith any Moderate or More Severe Injury to the Head, Neck, or Chest from Contacting a Frontal Component during a Rear Impact (1988-1990 NASS Front-Outboard Stats of Inspected Toved Cars)

Seat Performance	Belt Use	Lesser Damage	Actual Cases	Weighted Data	
No damage	No	None	4	1,654	69%
No damage	No	Front		583	24%
No damage	No	Side		150	6%
No damage	No	Total	I	2,387	100%
No damage	Yts	None	4	1,289	53%
No damage	Yes	Front	8	1,158	47%
No damage	Yes	Side	0	0	0%
No damage	Yes	Total	12	2,447	100%
Damaged	No	None	1	63	16%.
Damaged	No	Front	5	315	78%
Damaged	No	Side	2	27	7%
Damaged	No	Total	8	405	100%
Damaged	Yes	None	2	176	30%
Damaged	Yes	Front	2	302	51%
Damaged	Yes	Side	10	117	20%
Damaged	Yes	Unknown		76	-
Damaged	Yes	Total		671	100%

Rear Seat Occupancy, Injury, and Front Seat Damage

Front-outboard seat damage was more likely when the seat directly behind was occupied (that is, when someone was in the left-second seat behind a driver or in the right-second seat behind a right-front passenger) than when it was empty. The percentage of front seats that were damaged was:

- 10 percent with no occupant behind,
- 18 percent with one occupant behind, and
- 29 percent with multiple occupants behind (Table 27).

The association between seat damage and *rear-seat* occupancy is consistent with results from the Multidisciplinary Accident Investigation (*A Preliminary Evalution of Seat Back Locks for Two-Door Passenger Cars with Folding Front Seatbacks*, C. Rahane, Office of Plans and Policy, NHTSA, DOT-HS-807-067, February 1987). Front-seat damage in frontal impacts to the two-door cars included in those data (which were primarily models of the late 1960s and early 1970s) was more common if there were a rear-seat occupant, especially if the rear-seat occupant weighed at least 100 pounds.

Injury risk for those sitting alone in a rear seat was estimated after prorating those with any moderate injury from an unknown source (if they had none attributed to seatback contact) between the other two groups of moderately-injured occupants. Seven percent of these rear-seat occupants were moderately injured, including:

- 5 percent when the front seat was undamaged and
- 18 percent when the front seat was damaged.

The risk of injury in the front seat was higher:

- 9 percent in undamaged seats and
- 26 percent in damaged seats (Table 8)

The greater injury risk associated with front-seat damage may reflect the higher crash severity and vehicle intrusion that produce seat damage, as well as any direct effects of seat damage.

Table 27: Occupant Injury for those Sitting Behind the Front-Outboard Stats (1988-1990 NASS Inspected Tovtd Cars in Rollover, Frontal, Side, and Rear Impacts)

Seat Performance	Number of Rear Occupants	Moderate Injury from Front Seatback Contact	Actual Cases	Weighted Number	
No damage	None	No occupant	12,822	5,054,014	
No damage	One	No moderate injury	1,320	506,023	95.2%
No damage	One	AIS>=2, none from seat	69	11,562	3.0%
No damage	One	AIS>=2, caused by seat	25	6,743	1.8%
No damage	One	AIS>=2, unknown if seat	70	7,274	
No damage	Two or more	Multiple occupants	14	4,152	
No damage	Total	Total	14,320	5,589,769	100.0%
Damaged	None	No occupant	2,782	563,445	
Damaged	One	No moderate injury	454	96,815	82.0%
Damaged	One	AIS>=2, none from seat	73	7,687	7.6%
Damaged	One	AIS>=2, caused by seat	85	10,569	10.4%
Damaged	One	AIS>=2, unknown if seat	55	3,049	
Damaged	Two or more	Multiple occupants	10	1,675	
Damaged	Total	Total	3,459	683,241	100.0%

Among those sitting alone behind an occupied front seat, the estimated fraction with at least one moderate injury from seatback contact was almost six times as high when the front seat was damaged (10.4 percent) as when it was undamaged (1.8 percent). Among those moderately-injured in a seat behind an occupied front seat, almost three-fifths (57 percent) of those sitting behind damaged front seats had at least one moderate injury from seatback contact, compared to almost two-fifths (37 percent) of those sitting behind undamaged front seats. Some front seats may have been damaged when they were loaded by a rear-seat occupant: the crash may have forced the occupant against the front seat. In other cases, the rear-seat occupant may have been injured because the front seat intruded rearward. The available automated data on the type of seat damage will be described later in this report.

Table 28 shows the available data by impact type. Occupants sitting in the rear seat behind a damaged seat had a greater risk of moderate injury (compared to sitting behind an undamaged seat) for each impact type. And, in particular, the risk of moderate injury from seatback contact was much higher for occupants sitting behind damaged seats for four of five crash types (all except near-side damage). However, it is not clear whether front-seat damage contributed to the injury in the rear seat or whether both were caused by severe crash forces.

Table 28: Occupant Injury by Impact Type for those Sitting Behind the Front-Outboard Seats (1988-1990 NASS Inspected Towed Cars)

		No Seat Damage			Damaged Seat		
Impact Type	Moderate Injury from Front Seatback Contact	Actual Cases	Weighted Number		Actual Cases	Weighted Number	
Rollover	No occupant	1.189	401,571		290	37,327	
Rollover	No moderate injury	'126	45,498	90.2%	31	3,822	69.5%
Rollover	AIS>=2, none from seatback	16	2,067	9.5%	7	728	24.8%
Rollover	AIS>=2, caused by seatback	1	78	0.4%	3	166	5.7%
Rollover	AIS>=2, unknown if seatback	30	2,807		12	783	
Rollover	Multiple occupants	2	265		1	89	
Rollover	Total	1,364	452,287	100.0%	344	42,915	100.0%
Front	No occupant	7,680	2,865,472		849	115,152	
Front	No moderate injury	712	256,932	96.4%	246		79.6%
Front	AIS>=2, none from seatback	22	4,667	2.1%	15	40,476	4.3%
Front	AIS>=2, caused by seatback	18	3,254	1.5%	63	0,237	16: 1%
Front	AIS>=2, unknown if seatback	20	1,694		24	1,408	
Front	Multiple occupants	9	3.392		4	1.261	
Front	Total	8,461	3,135,410	100.0%	1,201	174,728	100.0%
Near-side	No occupant	1,493	712,335		832	166,634	
Near-side	No moderate injury	168	90,495	92.0%	74	13,409	73.2%
Near-side	AIS>=2, none from seatback	21	3.504	4.1%	44	4,341	25.0%
Near-side	AIS>=2, caused by seatback	2	3,319	3.9%	6	325	1.9%
Near-side	AIS>=2, unknown if seatback	5	1,037		9	249	
Near-side	Multiple occupants	1	48		1	26	
Near-side	Total	1,690	810,737	100.0%	966	104,984	100.0%
Far-side	No occupant	1,842	760,233		286	55,321	
Far-side	No moderate injury	201	69,007	96.2%	30	6,971	86.3%
Far-side	AIS>=2, none from seatback	8	1,223	3.7%	5	272	5.9%
Far-side	AIS>=2, caused by seatback	1	44	0.1%	7	355	7.7%
Far-side	AIS>=2, unknown if seatback	13	1,487		7	475	
Far-side	Multiple occupants	1	48		3	145	
Far-side	Total	2,066	832,043	100.0%	338	63,538	100.0%
Rear	No occupant	618	314,403		525	189,011	
Rear	No moderate injury	113	44,090	99.1%	73	26,196	93.9%
Rear	AIS>=2, none from seatback	2	101	0.6%	2	171	3.6%
Rear	AIS>=2, caused by seatback	3	48	0.3%	6	1,486	5.5%
Rear	AIS>=2, unknown if seatback	2	249		3	55	
Rear	Multiple occupants	1	400		1	155	
Rear	Total	739	359,292	100.0%	610	217,075	100.0%

A single year of NCSS data with detailed seat intrusion data were collected more than ten years before the NASS data described here, and reflect the experiences of earlier vehicle designs in previous years. Despite their age, the automated NCSS data are.useful because they include information on unoccupied seats; these data may suggest relationships that could be explored by reviewing the individual NASS case documents. or that could suggest additions to the NASS data collection forms,

The NCSS data on seat performance were defined as intrusions into a specific seat space (and include the direction of the intrusion into that space), rather than as damage to a particular seat. Results from NCSS and NASS data are not directly comparable: seat damage that did not result in intrusion is not described in NCSS, and it is sometimes difficult to determine from the NCSS automated data which seat was intruded into a particular space. Forward seat intrusion into the front seat and rearward seat intrusion into the second seat both imply that the front seat-was involved; the number, veighted number, and relative frequency of longitudinal intrusion are shown in Table 29.

The data suggest that both front-seat and rear-seat occupants contributed to the frequency of front-seat longitudinal intrusion. The percentage of front-outboard seats that were intruded forward or rearward in towavay car crashes was:

- 1.6 percent when both the front seat and the seat behind were unoccupied,
- 3.5 percent when the front seat was occupied and the seat behind was not,
- 8.7 percent when the front seat was unoccupied and the seat behind was occupied, and
- 14.5 percent when both the front seat and the seat behind were occupied.

The contribution of the rear-seat occupant to front-seat intrusion is suggested further by Table 29. More longitudinal front-seat intrusions were attributed to deformation from the rear passenger ~28.2 percent of all those with a single identified cause) than were attributed to deformation from the front passenger (25.2 percent of the known data). This occurred despite nine times as many front-seat occupants as rear-seat occupants in these crashes. Most occupants were unbelted at the time the NCSS data were collected, and there were almost no belted rear *seat* occupants then -- these data essentially reflect the experiences of unbelted occupants in older vehicles.

An estimated 7.5 percent of the front-seat intrusions were attributed to deformation from inertial forces caused by the mass of the seat. This type of damage is not included on the NASS automated file because it largely pertains to unoccupied seats. However, the prevalence of this type of damage in more recent vehicles could be estimated from a review of the detailed NASS case documents.

There were 413 fatalities in the towed cars that were inspected by the NCSS *teams* between April 1978 and March 1979 (in the last year of the study). The FARS national census of traffic fatalities includes 28,881 passenger car occupant fatalities during these twelve months, which *is 69.93 times* as many as investigated by NCSS. This factor can be used to make crude estimates of the number of front-outboard seat longitudinal intrusions that would have occurred during these twelve months if the NCSS sites were representative of the nation. The results are shown in Table 30.

Table 29: Occupancy and **Longitudinal** Intrusion into the Front- **and** Second-Outboard Stats
(**April 1978-March** 1979 NCSS Inspected Toved Cars)

Impact Type	Occupied Seats, Actual Cases: Neither	Front Only	Rear Only	Both	Total Seats	Occupied Seats, Weighted Data: Neither	Front Only	Rear Only	Both	Total Seats
OCCUPANCY										
Rollover	199	457	2	70	728	723	1,331	5	209	2,260
Front	1,916	3,709	18	507	6,150	0,981	15,800	52	1,697	26,530
Near-side	367	850	6	121	1,344	1,690	3,782	15	390	5,877
Far-side	401	826	8	109	1,344	1,910	3,526	29	412	5,877
Back	248	295	1	42	586	1,272	1,485	1	192	2,950
Other	29	65	0	14	108	119	251	0	70	440
Unknown	113	208	3	28	352	646	1,106	24	148	1,924
Total	3,273	6,410	38	891	10,612	15,341	27,281	126	3,118	45,866
LONGITUDINAL INTRUSION										
Rollover	9	35	0	6	50	9	59	0	6	74
Front	72	214	2	165	453	117	330	5	333	785
Near-side	39	127	2	23	191	72	222	5	40	347
Far-side	9	41	0	9	59	9	83	0	15	107
Back	12	75	1	8	96	33	243	1	17	294
Other	1	4	0	3	8	1	4	0	22	27
Unknown	1	5	0	5	11	1	5	0	11	17
Total	143	501	5	219	868	242	946	11	452	1,651
INTRUSIONS PER INVOLVEMENT										
Rollover						1.2%	4.4%	*	2.9%	3.3%
Front						1.3%	2.1%	*	19.6%	3.0%
Near-side						4.3%	5.9%	*	12.3%	5.9%
Far-side						0.5%	2.4%	*	3.6%	1.8%
Back						2.6%	16.4%	*	8.9%	10.0%
Total						1.6%	3.5%	8.7%	14.5%	3.6%

* Indicates fever than 25 observed tovdvay **crashes.**

Table 30: Specific Longitudinal Intrusion of the Front-Outboard **Seats**
(April **1978-March** 1979 NCSS Inspected Toved Cars)

Longitudinal Seat Intrusions	Actual Cases	Weighted Number		* Annual Estimate
Broken components:				
Seat adjusters	29	50	3.2%	3,496
Seat tracks	35	53	3.4%	3,706
Folding locks	44	129	8.3%	9,021
Deformed **by passenger:**				
From rear	219	437	28.2%	30,559
From front	163	391	25.2%	27.343
Deformed by:				
Inertial forces, mass **of** stat	89	348	22.4%	8,112
Compartment intrusion	216		1.8%	24,336
Other	19	28	.	
Combination	14	23		1,958
Unknown	40	76		1,608
Total	868	1,651	100.0%	115,454

- Estimated **by** inflating the NCSS veighttd data **by a factor of 69.93** to approximate the relationship betvcen NCSS **dnd FARS** fatalities.

Crash Severity by Seat Damage

Seat damage was much more likely at higher crash speeds, as indicated by the proportion of vehicles with extensive vehicle crush -- defined as crush to extent zone three arid beyond (Table 31). Vehicle crush reflects a variety of factors , including the specific vehicle area damaged, the vehicle stiffness at the damage point, the size of the damaged area, and crash severity. Thus, the percent of crash-involved vehicles with a crush extent zone of three or beyond can only suggest the relationship between crash severity and seat damage.

Table 31: Seat Performance and Damage Extent Zone
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Impact Type	Seat Performance	Extent Zone >=3	Actual Cases	Weighted Number	
Rollover	No damage	No	379	158,732	37%
Rollover	No damage	Yes	925	275,674	63%
Rollover	No damage	Unknown	60	17,881	
Rollover	No damage	Total	1,364	452,287	100%
Rollover	Damaged	No	40	4,982	12%
Rollover	Damaged	Yes	284	36,670	88%
Rollover	Damaged	Unknown	20	1,262	
Rollover	Damaged	Total	344	42,915	100%
Front	No damage	No	6,430	2,603,817	83%
Front	No damage	Yes	2,031	531,594	17%
Front	Ho damage	Total	8,461	3,135,410	100%
Front	Damaged	No	481	103,375	59%
Front	Damaged	Yes	720	71,353	41%
Front	Damaged	Total	1,201	174,728	100%
Near-side	No damage	No	1,023	540,802	67%
Near-side	No damage	Yes	667	269,935	33%
Near-side	No damage	Total	1,690	810,737	100%
Near-side	Damaged	No	134	35,647	19%
Near-side	Damaged	Yes	832	149,337	81%
Near-side	Damaged	Total	966	184,984	100%
Far-side	No damage	No	989	504,284	61%
Far-side	No damage	Yes	1,077	327,758	39%
Far-side	No damage	Total	2,066	832,043	100%
Far-side	Damaged	No	29	6,896	11%
Far-side	Damaged	Yes	309	56,643	89%
Far-side	Damaged	Total	338	63,538	100%
Rear	No damage	No	497	264,570	74%
Rear	No damage	Yes	242	94,723	26%
Rear	No damage	Total	739	359,292	100%
Rear	Damaged	No	255	99,137	46%
Rear	Damaged	Yes	355	117,938	54%
Rear	Damaged	Total	610	217,075	100%

There are no identified front, near-side, far-side, or rear nonrollover crashes with unknown extent zone because nonrollover damage area and extent zone are coder! together as part of the Collision Deformation Classification.

The fraction of occupants in vehicles with crush to extent zones three and beyond is estimated from Table 31, as follows.

Percent of Occupants, Extent Zone>=

	N o	Damaged Seat
Rollover	63 percent	88 percent
Front	17 percent	4’1 percent
Near-side	33 percent	81 percent
Far-side	39 percent	89 percent
Rear	26 percent	54 percent

The data in Table 31 can also be used to estimate the risk of seat damage for vehicles with ● xtensiye (tone three and above) crush damage. More than half of all occupied seats were damaged in vehicles with extensive rear crush. The risk of seat damage was less for other vehicle impact types:

12 percent in vehicles with extensive crush in a rollover,
12 percent in vehicles with extensive frontal crush,
36 percent in vehicles with extensive near-side crush,
15 percent in vehicles with extensive far-side crush, and
55 percent in vehicles with extensive rear crush.

Extent zone three to the side is crush a quarter of the way into the vehicle, so the seats in crashes with extensive near-side crush (extent zone three and beyond) may have been directly damaged by intrusion (depending on the exact crush location along the side). In contrast, extent zone three to the top (such as occurs in some rollovers), to the far-side, and to the front need not involve intrusion into the seat. This probably explains why seat damage was more common in near-side impacts than in rollovers, frontal impacts, and far-side impacts among crashes with crush to extent zone three. Extent zone three in the rear would not generally involve front-seat damage from intrusion. The high risk of seat damage in rear impacts largely reflects nonintrusion seat damage. The 1990 and later years of NASS include more details on the type of seat damage, and these will be explored later in this report.

Delta V is a better measure of the forces on the vehicle and occupants than is extent zone, but delta V is less-frequently available. Delta V is not defined for rollover and other nonhorizontal events, and there is no good alternative severity measure for these crashes. When delta V is estimated for a rollover crash, it reflects the severity of another impact to the vehicle. Delta V could not be estimated for 42 percent of inspected nonrollover crashes -- either because the crash was too complicated for the delta V algorithm or because the damage data were incomplete or contradictory. Vehicles for which delta V was estimated may not be typical of all towaway crashes.

The data show that a larger fraction of damaged seats than of undamaged seats were exposed to a severe delta V (defined as at least 30 mph, Table 32). For example, in frontal crashes 15.0 percent of damaged seats compared to 1.3 percent of undamaged seats had a delta V this severe.

Percent of Occupants, Delta V>=30 mph

	No Seat Damage	Damaged Seat
Front	1.3 percent	15.0 percent
Near- side	0.0 percent	3.2 percent
Far-side	0.4 percent	5 .1 percent
Rear	0.4 percent	4’. 3 percent

Table 32: Seat Performance and Delta V
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Impact Type	Seat Performance	Delta V >=30 mph	Actual Cases	Weighted Number	
Rollover	No damage	No	86	11,285	
Rollover	No damage	Yes	16	1,306	
Rollover	No damage	Unknown	1,262	439,696	
Rollover	No damage	Total	1,364	452,287	
Rollover	Damaged	No	43	4,087	
Rollover	Damaged	Yes	23	1,601	
Rollover	Damaged	Unknown	278	37,227	
Rollover	Damaged	Total	344	42,915	
Front	No damage	No	4,784	1,547,669	98.7%
Front	No damage	Yes	220	21,168	1.3%
Front	No damage	Unknown	3,457	1,566,573	
Front	No damage	Total	8,461	3,135,410	100.0%
Front	Damaged	No	484	81,261	85.0%
Front	Damaged	Yes	204	14,368	15.0%
Front	Damaged	Unknown	513	79,100	
Front	Damaged	Total	1,201	174,728	100.0%
Hear-side	Ho damage	No	896	413,183	100.0%
Near-side	No damage	Yes	1	21	0.0%
Near-side	No damage	Unknown	793	397,533	
Near-side	Ho damage	Total	1,690	810,737	100.0%
Near-side	Damaged	No	512	94,363	96.8%
Near-side	Damaged	Yes	42	3,162	3.2%
Near-side	Damaged	Unknown	412	87,458	
Near-side	Damaged	Total	966	184,984	100.0%
Far-side	No damage	No	1,130	443,794	99.6%
Far-side	No damage	Yes	22	1,749	0.4%
Far-side	No damage	Unknown	914	386,499	
Far-side	No damage	Total	2,066	832,043	100.0%
Far-side	Damaged	No	154	33,761	94.9%
Far-side	Damaged	Yes	33	1,801	5.1%
Far-side	Damaged	Unknown	151	27,977	
Far-side	Damaged	Total	338	63,538	100.0%
Rear	No damage	No	428	203,806	99.6%
Rear	Ho damage	Yes	8	772	0.4%
Rear	No damage	Unknown	303	154,714	
Rear	No damage	Total	739	359,292	100.0%
Rear	Damaged	No	348	118,355	95.7%
Rear	Damaged	Yes	34	5,256	4.3%
Rear	Damaged	Unknown	228	93,465	
Rear	Damaged	Total	610	217,075	100.0%

These data can also be used to estimate the risk of seat damage for vehicles with severe delta-V (30 mph and above). The fraction of seats damaged was:

40 percent in severe frontal impacts,
99 percent in severe near-side impacts,
51 percent in severe far-side impacts, and
87 percent in severe rear impacts.

The differences in crash severity indicate why the effect of seat damage on safety cannot be estimated by simply comparing injury risk in damaged and undamaged seats. The severity of the crash is responsible for both seat damage and injury severity, and the separate effect of seat damage on injury severity is not easy to estimate from the aggregated data.

To explore crash severity biases in the comparison of damaged and undamaged seats, injuries were counted within ten mph delta V categories. There were insufficient data to separate belted and unbelted occupants, so all occupants (regardless of belt use) were combined. The data in Table 33 show the total number of occupants, the number with moderate (AIS=2) injury, and the number with serious and more severe (AIS>=3) injury. The moderate injury rate (the fraction of involved occupants who received a moderate or more severe injury -- AIS>=2) and the serious injury rate (those with serious or more severe injury -- AIS>=3) are shown in Table 34. An injury ratio was calculated as the injury rate in damaged seats divided by the injury rate in undamaged seats, to measure the association between injury severity and seat performance within categories of damage severity.

Much of the association between injury risk and seat performance is accounted for by crash severity: the injury rate ratio tended to be smaller within categories of delta V than overall. For example, the injury rate in frontal crashes was 3.5 times as high for occupants of damaged seats as for occupants of undamaged seats, but the highest injury rate ratio within delta V categories was 2.3 (for lo-to-19 mph crashes) and it was much lover in other delta V ranges. However, the injury rate ratio for frontal crashes was at least 1.1 in each comparison that had at least 25 involved occupants, indicating that occupants of damaged seats were more likely than occupants of undamaged seats to be injured in crashes at similar delta Vs. The comparisons are summarized below: ratios based on a particularly small number of cases are indicated by an asterisk and the footnote.

	Moderate Injury Rate Ratio			
Delta V, mph	Front	Near-Side	Far Side	Rear
Delta V 00-09	0.0*	7.6	0.1*	5.2*
Delta V 10-19	2.3	4.1	1.5	1.4
Delta V 20-29	1.7	2.6	1.3	0.5
Delta V 30-39	1.2	0.7*	1.3*	0.4*
Delta V 40 up	1.1	-*	1.0*	0.4*
All vehicles	3.5	5.8	2.9	1.8

• Indicates comparisons based on fever than 25 involved occupants in either undamaged or in damaged seats.

These data suggest that injury risk is greater in damaged than in undamaged seats within most delta V ranges if the comparisons are limited to situations with at least 25 actual [illegible] of undamaged and of damaged seats. For both near-side and far-side crashes, seat damage may act as a surrogate for the extent of passenger compartment intrusion, even within delta V ranges; it is not clear how the observed patterns should be interpreted. Comparisons for rear impacts are limited by the small number of moderate injuries investigated; it is not clear from these comparisons how, or whether, the injury rate-tatio varies with delta V in rear impacts.

The data for each vehicle impact type include a mix of seat damage types (broken seat components, deformation from occupant loading, and deformation from vehicle intrusion), and the relative frequency of these seat damage types and their injury consequences differ by impact type, as indicated by the detailed 1990 SASS seat damage data described later in this report.

Table 33: Impact Type, Seat Performance, Delta V in mph, and Injury Severity
(1988-1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Impact Type	Seat Performance	Total Delta V	Actual Cases Total	Actual Cases AIS=2	Actual Cases AIS>=3	Weighted Number Total	Weighted Number AIS=2	Weighted Number AIS>=3
Front	No damage	00-09	621	23	3	318,582	3,356	429
Front	Ho damage	10-19	3,075	409	95	1,041,861	78,066	10,432
Front	No damage	20-29	1,088	288	190	187,226	36,660	16,630
Front	Ho damage	30-39	180	49	63	17,186	5,158	4,582
Front	No damage	40 +	40	9	25	3,982	1,529	1,756
Front	No damage	Unknown	3,457	467	268	1,566,573	109,561	29,617
Front	No damage	Total	8,461	1,245	644	3,135,410	234,329	63,446
Front	Damaged	00-09	14	0	0	4,641	0	0
Front	Damaged	10-19	242	43	22	51,534	6,936	3,050
Front	Damaged	20-29	228	56	69	25,086	6,919	5,229
Front	Damaged	30-39	134	20	88	10,782	2,683	4,530
Front	Damaged	40 +	70	9	56	3,586	378	2,970
Front	Damaged	Unknown	513	92	191	79,100	13,241	12,731
Front	Damaged	Total	1,201	220	426	174,728	30,158	28,510
Near-side	No damage	00-09	279	23	4	174,723	5,085	470
Near-side	No damage	10-19	550	85	37	224,359	15,467	4,612
[illegible]	[illegible]	20-29	67	19	13	14,100	2,420	711
Near-side	Ho damage	30-39	1	0	1	21	0	21
Near-side	No damage	40 +	0	0	0	0	0	0
Near-side	No damage	Unknown	793	96	45	397,533	18,881	5,814
Near-side	No damage	Total	1,690	223	100	810,737	41,853	11,628
Near-side	Damaged	00-09	31	4	3	8,537	1,786	272
Near-side	Damaged	10-19	288	69	62	64,267	14,008	9,530
Near-side	Damaged	20-29	193	46	98	21,559	5,932	6,694
Near-side	Damaged	30-39	37	3	31	2,769	209	1,867
Near-side	Damaged	40 +	5	1	3	393	44	202
Near-side	Damaged	Unknown	412	69	193	87,458	9,660	20,961
Near-side	Damaged	Total	966	192	390	184,984	31,639	39,526
tar-sidt	No damage	00-09	267	20	1	166,058	7,709	154
Far-sidt	No damage	10-19	688	103	30	253,696	17,036	3,129
far-side	No damage	20-29	175	36	36	24,040	4,717	2,611
Far-sidt	No damage	30-39	18	3	11	1,596	289	701
Far-sidt	No damage	40 +	4	1	3	154	21	133
Far-side	No damage	Unknown	914	88	60	386,499	23,842	4,788
Far-side	No damage	Total	2,066	251	141	832,043	53,614	11,516
Far-sidt	Damaged	00-09	9	1	0	2,685	13	0
Far-side	Damaged	10-19	69	12	11	22,605	2,065	643
Far-side	Damaged	20-29	76	13	28	8,471	662	2,794
Far-side	Damaged	30-39	25	4	16	1,094	143	725
Far-side	Damaged	40 +	8	1	7	706	220	486
Far-side	Damaged	Unknown	151	22	60	27,977	2,829	3,761
Far-side	Damaged	Total	338	53	122	63,538	5,932	8,409
Rtar	No damage	00-09	34	2	1	13,925	383	98
Rtar	No damage	10-19	329	12	1	174,765	2,353	1,051
Rear	No damage	20-29	65	5	3	15,116	1,513	131
Rear	No damage	30-39	5	3	0	731	432	0
Rear	No damage	40 +	3	0	2	41	0	28
Rear	No damage	Unknown	303	20	6	154,714	4,422	633
Rear	No damage	Total	739	42	13	359,292	9,103	1,971
Rear	Damaged	00-09	12	1	0	4,225	766	0
Rear	Damaged	10-19	232	13	2	89,934	2,355	181
Rear	Damaged	20-29	104	11	2	24,196	1,203	130
Rear	Damaged	30-39	22	4	3	4,374	553	412
Rear	Damaged	40 +	12	2	5	882	121	106
Rear	Damaged	Unknown	228	21	19	93,465	4,374	1,672
Rear	Damaged	Total	610	52	31	217,075	9,372	2,502

Table 34: Impact Type, Seat Performance, Delta V in mph, and Injury Rates (1988-1990 NASS Front-Outboard Stats of Inspected Toved Cars)

Impact Type	Stat Performance	Total Delta V	Injury Rates AIS>=2	Injury Rates AIS>=3	Injury Ratio: Damagtd Rate/ Undamaged Rate AIS>=2	Injury Ratio: Damagtd Rate/ Undamaged Rate AIS>=3
Front	No damage	00-09	1.2%	0.1%		
-Front	No damage	10-19	8.5%	1.0%		
Front	No damage	20-29	28.5%	8.9%		
Frcnt	No damage	30-39	56.7%	26.7%		
Front	No damage	40 +	82.5%	44.1%		
Front	No damage	Unknown				
Front	No damage	Total	9.5%	2.0%		
Front	Damagtd	00-09	0.0%	0.0%	0.0	0.0
Pront	Damagtd	10-19	19.4%	5.9%	2.3	5.9
Front	Damaged	20-29	48.4%	20.8%	1.7	2.3
Front	Damaged	30-39	66.9%	42.0%	1.2	1.6
Front	Damaged	40 +	93.4%	82.8%	1.1	1.9
Frcnt	Damaged	Unknown				
Front	.amaged	Total	33.6%	16.3%	3.5	8.1
Near-side	No damage	00-09	3.2%	0.3%		
Near-sib	No damage	10-19	0.9%	2.1%		
Near-side	No damage	20-29	22.2%	5.0%		
Near-side	No damage	30-39	100.0%	100.0%		
Sear-side	No damage	40 +	-	-		
Near-side	No damage	Unknown				
Near-side	No damage	Total	6.6%	1.4%		
Near-side	Damaged	00-09	24.1%	3.2%	7.6	11.8
Near-side	Damaged	10-19	36.6%	14.8%	4.1	7.2
Near-side	Damaged	20-29	58.6%	31.0%	2.6	6.2
Near-side	Damaged	30-39	75.0%	67.4%	0.7	0.7
Near-side	Damaged	40 •	62.2%	51.4%	-	
!ear-si	Damaged	Unknown				
Near-side	Damaged	Total	38.5%	21.4%	5.8	14.9
Far-side	No damage	00-09	4.7%	0.1%		
Far-side	No damage	10-19	1.9%	1.2%		
Far -side	No damage	20-29	30.5%	10.9%		
Far-side	No damage	30-39	62.0%	43.9%		
Far-side	No damage	40 +	100.0%	86.4%		
F r-sid	No damage	Unknown				
Par-side	No damage	Total	7.8%	1.4%		
Far-side	Damaged	00-09	0.5%	0.0%	0.1	0.0
Far-side	Damaged	10-19	12.0%	2.8%	1.5	2.3
Far-side	Damaged	20-29	40.8%	33.0%	1.3	3.0
Far-side	Damaged	30-39	79.3%	66.3%	1.3	1.5
Far-side	Damaged	40 •	100.0%	68.8%	1.0	0.8
Far-side	Damaged	Unknown				
Far-side	Damaged	Total	22.6%	13.2%	2.9	3.6
Rear	No damage	00-09	3.5%	0.7%		
Rear	No damage	10-19	1.9%	0.6%		
Rear	No damage	20-29	10:9x	0.9%		
Rear	No damage	30-39	59.1%	0.0%		
Rear	No damage	40 +	68.3%	68.3%		
Rear	No damage	Unknown				
Rear	No damage	Total	3.1%	0.5%		
Rear	Damaged	00-09	18.1%	0.0%	5.2	0.0
Rear	Damaged	10-19	2.8%	0.2%	1.4	0.3
Rear	Damaged	23-29	5.X	0.5%	0.5	0.6
Rear	Damaged	30-39	22.1%	9.4%	0.4	-
Rear	Damaged	[illegible] •	25.7%	12.0%	0.4	0.2
Rear	Damaged	Unknown				
Rear	Damaged	Total	5.5%	1.2%	1.8	2.1

Matched-Pairs Comparison

Drivers and right-front passengers together in a car are exposed to the same vehicle crash (though not necessarily to the same injury risk), which suggests that it might be possible to compare their injuries to gain some insight into the association between seat damage and injury. This is the basic idea behind the matched-pairs analytical method that has been used with FARS data, primarily in studies of safety belt effectiveness; it is described by Leonard Evans in "Double Pair Comparison -- A Mew Method to Determine How Occupant Characteristics Affect Fatality Risk in Traffic Crashes," *Accident Analysis* and *Prevention*, Volume 18, Number 3, pages 217-227, June 1986.

Table 35 shows the number of towed cars that had two front-outboard occupants with known seat performance and provides a comparison of the risk of moderate injury by seat damage. Only front and rear impacts are included here, because rollover and side impacts seem less likely to involve crash forces that are similar for the two positions. However, comparisons of injuries by seat performance may be confounded by differences in the severity of the crash as experienced by each occupant, even for two occupants within the same vehicle. For vehicles with both a damaged and an undamaged front-outboard seat, the occupant in the damaged seat may have been exposed to the more severe crash forces or to greater intrusion. As a result, this method may confirm the association between seat damage and injury (while using another method of accounting for differences in delta V), but it still cannot identify seat damage as the unambiguous cause of any observed differences.

Table 35: Injuries in Vehicles with Both and Driver and a Right-Front Passenger
(1988-1990 NASS Front-Outboard Stats of Inspected Towed Cars)

		Actual Cases			Weighted Number					Injury Rate Ratio	
Impact Type	Stars Damaged	Total Cases	Number Injured Driver	Number Injured RF Pass	Total Number	Number Injured Driver	Number Injured RF Pass	Percent Injured Driver	Percent Injured RF Pass	Driver/ RF Pass	RF Pass /Driver
Rear, rtgardltss of belt use											
	Xtither	192	10	10	98,082	3,040	2,003	3.10%	2.04%	1.52	0.66
	RF Pass	25	5	2	10,689	364	77	3.41%	0.72%	4.73	0.21
	Driver	40	6	3	14,154	1,052	232			4.53	0.22
	Both	149	19	17	46,978	2,872	2,641	7.43%	1.64%	1.09	0.92
								6.11%	5.62%		
Front, rtgardltss of belt use											
	Ntithtr	1,936	303	373	690,582	43,820	64,340	6.35%	9.32%	0.68	1.47
	RF Pass	139	48	57	28,468	5,720	8,145	20.09%	28.61%	0.70	1.42
	Driver	123	57	45	31,159	9,051 5,761	13,061	29.05%	35.36% 15.37%	1.88	0.53
	Both	231	104	106						0.82	1.22
Front, ntithtr occupant btlttd											
	Ntithtr	740	142	197	222,615	17,290	32,219	7.77%	14.47%	0.54	1.86
	RF Pass	67	27	29	13,528	3,149	3,493	23.28%	25.82%	0.90	1.11
	Drivtr	75	31	32	10,317	2,148	2,440	20.82%	23.65%	0.88	1.14
	Both	139	65	67	18,479	5,686	6,010	30.77%	32.52%	0.95	1.06
Front, both occupants belted											
	Neither	880	99	103	376,529	17,325	19,997	4.60%	5.31%	0.87	1.15
	RF Pass	45	18	18	9,663	2,218	2,941	22.95%	30.44-z	0.75	1.33
	Driver	29	12	6	6,066	495	159	8.16%	2.62%	3.11	0.32
	Both	51	19	21	8,631	1,205	2,957	13.96%	34.26%	0.41	2.45

The matched-pairs method attempts to control for differences in crash severity (both occupants in a single car are exposed to the same delta V), but comparisons of injuries in the two seats are complicated by differences in their inherent safety risks (the two occupants are near different structures, and a specific crash configuration may be more hazardous to one occupant than the other) and differences in seat design (the driver seat may offer more adjustments, and it may be designed differently in other ways as well). As a result, one position may tend to have more injuries than the other, and seat damage may involve different risks for the two occupants. It is not clear that these differences invalidate the comparison of ratios used in the matched-pairs technique, but the possibility of confounding factors should be considered in considering the results.

There were very few moderately-injured occupants in rear impacts in these data, which limits the accuracy of the estimates. It appears that drivers were injured more frequently than their right-front passengers (labeled RF Pass in the table), for belted and unbelted occupants combined, but it is not clear that seat damage was associated with differences in moderate injury risk. The number of injured drivers was higher than the number of injured right-front passengers (in cars that included occupants in both positions) in rear impacts, by factors of:

4.73 when only the passenger seat was damaged,
1.52 when neither seat was damaged,
1.09 when both seats were damaged, and
4.53 when only the driver seat was damaged.

If seat damage were associated with injury, the values on this list would be expected to increase (with the two situations of similar seat damage -- neither seat damaged and both seats damaged -- having injury ratios similar to each other and between the other two values). It was relatively uncommon for only one of the front-outboard seats in a rear towaway impact to be damaged, and this limits the data available for comparing injury outcomes by seat performance.

There were more data for moderately-injured occupants in frontal impacts because there were both more frontal impacts and a greater likelihood of injury in these impacts (compared to the experience in rear impacts). This provides a better basis for exploring the association between seat performance and injury, but the effect of seat damage in frontal impacts may not be the same as in rear damage types. Right-front passengers were injured more often than their drivers in frontal towaway impacts (for belted and unbelted occupants, combined) for three of four seat damage categories; the exception was that when only the driver seat was damaged, more drivers than right-front passengers were injured. The ratio of the driver to right-front passenger injuries (in cars that included occupants in both positions) in frontal impacts was:

0.70 when only the passenger seat was damaged,
0.68 when neither seat was damaged,
0.82 when both seats were damaged, and
1.88 when only the driver seat was damaged.

The higher driver injury ratio when only the driver seat was damaged (1.88) compared to the ratio when only the passenger seat was damaged (0.70) is consistent with the direction that would be expected if driver seat damage increased injury risk in frontal impacts. However, the pattern would be more convincing if the driver injury ratios for the two similar-damage situations (neither or both seats damaged) were closer to 1.3 (between the two extreme situations).

Belt use was the same for both front-outboard passengers (either both were unbelted or both were belted) in most frontal crashes. Belt use was unknown or differed for the two passengers for some cases; these are included in Front, regardless of belt use but not in either of the two groups Front, neither occupant belted and Front, both occupants belted in Table 35. For the cases where neither occupant was belted, more right-front passengers than drivers were injured in all four seat damage categories. However, there does not seem to be any pattern between seat damage and the driver injury ratio. The ratio of driver to right-front passenger injuries among unbelted occupants in frontal impacts was:

- 0.90 when only the passenger seat was damaged,
- 0.54 when neither seat was damaged,
- 0.95 when both seats were damaged, and
- 0.88 when only the driver seat was damaged.

The driver injury ratio was higher when any seat was damaged than when no seat was damaged, but there is no obvious meaningful explanation of this effect. These ratios do not suggest that risk injury among unbelted occupants in frontal crashes increased when their seat *was* damaged.

For the *cases* where both the driver and right-front passenger were belted in a frontal crash, there were more injured drivers than right-front passengers for three of four comparisons. The driver injury ratio among belted occupants was:

- 0.75 when only the passenger seat was damaged,
- 0.87 when neither seat was damaged,
- 0.41 when both seats were damaged, and
- 3.11 when only the driver seat was damaged*

This large difference in driver injury rate ratios between cases where only the driver seat was damaged (a ratio of 3.11) and all other cases (ratios ranging from 0.41 *to* 0.87) may be a random effect of the small number of injured belted occupants in these data. The comparison between the two situations with a single damaged seat (for which the driver injury ratios were 0.75 and 3.11) might suggest that driver seat damage is associated with a greater injury risk among belted drivers in frontal crashes- However, the ratios for the two similar-damage cases do not fall between these two values and so do not support this interpretation.

All four comparisons in Table 35 may simply indicate that there are too few NASS data for this type of analysis, and this may lead to seemingly inconsistent results. It would be useful to attempt to perform this type of analysis cn a larger data file, but seat damage information is not currently available on FARS or any state accident data file.

Seat Damage Type

The 1990 NASS data indicate that seat damage was more often intrusion-caused deformation (42 percent of damaged seats with one damage type) or deformation from occupant loading (35 percent) than it was broken seat adjusters, folding locks, tracks, and anchors (23 percent combined, Table 36).

Table 36: Detailed Seat Performance
(1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Seat Performance	Actual Cases	Weighted Number	
No damage	6,159	2,309,639	
Seat Jdjusters broken	75	16,974	7%
Folding locks broken	105	27,071	11%
Track/anchors broken	64	12,733	5%
Deformed by occupant	316	88,701	35%
Deformed by intrusion	450	104,578	42%
Conbination	a5	12,288	
Other	61	13,610	
Unknown	151	44,410	
Total	7,466	2,630,003	100%

Nonfolding seats had almost twice as much deformation from occupant loading as from intrusion. In contrast, folding seats had two or three times as much deformation from intrusion as from occupant contact (Table 37). Broken seat components accounted for:

17 percent of damage in bucket seats without a folding back,
28 percent of damage in bucket seats with a folding back,
20 percent of damage in bench seats without a folding back, and
12 percent of damage in bench seats with a folding back.

The vehicle impact type appears related to the type of seat damage (Table 38). Seat breakage (as opposed to deformed seats) accounted for the following percentages of damaged seats:

45 percent in rollover crashes,
45 percent in frontal impacts,
3 percent in near-side impacts,
22 percent in far-side impacts, and
28 percent in rear impacts.

Most seat breakage in rollovers (and accounting for 40 percent of all seat damage in rollovers) involved the folding locks. This is higher than the proportions in the other four vehicle impact types. Deformation from occupant contact accounted for 71 percent of seats damaged in rear impacts and 42 percent in frontal impacts; most seat damage in side impacts was intrusion-caused deformation (90 percent in near-side and 71 percent in far-side crashes).

The risk of moderate injury differed by vehicle impact type and seat performance as shown in Tables 39 to 43.

Table 37: Seat Type and Detailed Stat Performance
(1990 NASS Front-Outboard Stats of Inspected Towed Cars)

Seat Type	Seat Performance	Actual Cases	Weighted Number	Percent of Damaged Seats
Bucket, not folding	No seat damage	1,363	543,939	
Bucket, not folding	Seat adjuster broken	20	6,212	11%
Bucktt, not folding	Folding lock broktn	12	1,481	3%
Bucket, not folding	Track/anchor broken	12	2,398	4%
Bucket, not folding	Deformed by occupant	84	31,113	53%
Bucktt, not folding	Deformed by intrusion	117	17,249	30%
Bucktt, not folding	Other or combination	25	4,656	
Bucket, not folding	Unknown	25	8,753	
Bucket, not folding	Total	1,658	615,802	100%
Bucket, folding	No seat damage	2,879	1,104,670	
Bucktt, folding	Seat adjuster broken	23	3,889	3%
Bucket , folding	Folding lock broktn	76	23,390	20%
Bucket, folding	Track/anchor broken	31	6,504	5%
Bucket , folding	Deformed by occupant	116	26,857	22%
Bucktt, folding	Deformed by intrusion	206	58,817	49%
Bucket, folding	Othtr or combination	74	16,269	
Bucket, folding	Unknown	46	11,225	
Bucket, folding	Total	3,451	1,251,620	100%
Bench, not folding	No seat damage	1,423	470,308	
Bench, not folding	Seat adjuster broktn	27	6,079	11%
Bench, nor folding	Folding lock broken	10	1,085	2%
Btnch, not folding	Track/anchor broktn	18	3,599	7%
Bench, not folding	Deformed by occupant	91	26,932	50%
Bench, not folding	Deformed by intrusion	81	16,073	30%
Bench, not folding	Other or combination	33	3,436	
Bench, not folding	Unknown	22	3,503	
Bench, not folding	Total	1,705	531,016	100%
Bench, folding	No seat damage	489	188,924	
Bench, folding	Seat adjuster broktn	5	793	4%
Bench, folding	Folding lock broktn	7	1,115	6%
Bench, folding	Track/anchor broktn	3	232	1%
Bench, folding	Deformed by occupant	24	3,762	21%
Bench, folding	Deformed by intrusion	45	12,389	68%
Bench, folding	Other or combination	14	1,538	
Bench, folding	Unknown	9	1,335	
Bench, folding	Total	596	210,089	100%
Other type	No seat damage	5	1,798	
Other type	Deformed by occupant	1	37	
Other type	Deformed by intrusion	1	50	
Othtr type	Total	7	1,885	
Unknown typt	Unknown	49	19,593	
Total	Total	7,466	2,630,003	

Table 38: Detailed Seat Performance
(1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Damage Area	Seat Performance	Actual Cases	Weighted Number	Percent of Damaged Seats
Rollover	No damage	544	200.200	
Rollover	Seat adjusters broken	6	539	4%
Rollover	Folding locks broken	18	5,040	40%
Rollover	Track/anchors broken	3	165	1%
Rollover	Deformed by occupant	22	3,545	28%
Rollover	Deformed by intrusion	34	3,358	27%
Rollover	Other or combination	11	1,809	
Rollover	Unknown	11	2,794	
Rollover	Total	649	217,449	100%
Front	No damage	3,313	1,184,634	
Front	Seat adjusters broken	26	3,347	11%
Front	Folding locks broken	37	9,335	19%
Front	Track/anchors broken	40	7,475	15%
Front	Deformed by occupant	116	20,562	42%
Front	Deformed by intrusion	66	6.169	13%
Front	Other or combination	72	10: 754	
Front	Unknown	85	24,880	
Front	Total	3,755	1,269,156	100%
Near-side	No damage	672	263,622	
Near-side	Seat adjusters broken	10	1.127	1%
Near-side	Folding locks broken	4	465	1%
Near-side	Track/anchors broken	3	a79	1%
Near-side	Deformed by occupant		5,738	7%
Near-side	Deformed by intrusion	2::	76,649	90%
Near-side	Other or combination	18	2,124	
Near-side	Unknown	13	6,268	
Near-side	Total	1,019	356,872	100%
Far-side	No damage	806	296,580	
Far-side	Stat adjusters broken	8	1.061	5%
Far-side	Folding locks broken	6	1,136	6%
Far-side	Track/anchors broken	5	2,029	10%
Fir-side	Deformed by occupant	14	1,300	7%
Far-side	Deformed by intrusion	56	13,821	71%
Far-side	Other or combination	14	2,498	
Far-side	Unknown	11	1,331	
Far-side	Total	920	319,756	100%
Rear	No damage	306	143,031	
Rear	Seat adjusters broken	25	8,899	11%
Rear	Folding locks broken	40	11,095	14%
Rear	Track/anchors broken	12	2,043	3%
Rear	Deformed by occupant	126	56,578	71%
Rear	Deformed by intrusion	5	558	1%
Rear	Other or combination	28	8,398	
Rear	Unknown	6	1,241	
Rear	Total	548	231,843	100%

Table 39: Seat Performance and Injury Stverity in Rollovers
(1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Seat Performance	Injury Severity	Actual Cases	Weighted Number	Injurtd AIS 2+
No seat damage	Uninjured	91	69,012	
No seat damage	AIS 1	256	98,673	
No seat damage	AIS 2	114	22,398	
No seat damage	AIS 3-6	83	10,117	
No damage	Total	544	200,200	16%
Component broktn	Uninjured	1	312	
Component broken	AIS 1	12	3,885	
Component broktn	AIS 2	6	1,125	
Component broken	AIS 3-6	8	422	
Component broktn	Total	27	5,744	27%
Deformed by occupant	Uninjured	1	398	
Deformed by occupant	AIS 1	10	1,898	
Deformed by occupant	AIS 2	8	1,189	
Deformed by occupant	AIS 3-6	3	60	
Deformed by occupant	Total	22	3,545	35%
Deformed by intrusion	Uninjured	1	521	
Deformed by intrusion	AIS 1	9	581	
Deformed by intrusion	AIS 2	7	1,240	
Deformed by intrusion	AIS 3-6	17	1,017	
Deformed by intrusion	Total	34	3,358	67%
Other or combination	Uninjured	0	0	
Other or combination	AIS 1	3	1,023	
Other or combination	AIS 2	3	26	
Other or combination	AIS 3-6	5	759	
Other or combination	Total	11	1,809	

Table 40: Stat Performance and Injury Severity in Frontal Impacts
(1990 NASS Front-Outboard Seats of Inspected Towed Cars)

Seat Performance	Injury Severity	Actual Cases	Weighted Number	Injured AIS 2+
No seat damage	Uninjured	884	567,930	
No seat damage	AIS 1	1,729	495,080	
No seat damage	AIS 2	485	93,674	
No seat damage	AIS 3-6	215	27,951	
No seat damage	Total	3,313	1,184,634	10%
Component broken	Uninjured	8	4,431	
Component broken	AIS 1	46	10,669	
Component broktn	AIS 2	23	4,164	
Component broken	AIS 3-6	26	2,891	
Component broktn	Total	103	22,156	32%
Deformed by occupant	Uninjured	7	331	
Dtfomed by occupant	AIS 1	67	13,268	
Deformed by occupant	AIS 2	20	4,492	
Deformed by occupant	AIS 3-6	22	2,471	
Deformed by occupant	Total	116	20,562	34%
Deformed by intrusion	Uninjured	1	21	
Deformed by intrusion	AIS 1	14	2,041	
Deformed by intrusion	AIS 2	16	1,149	
Deformed by intrusion	AIS 3-6	35	2,959	
Deformed by intrusion	Total	66	6,169	67%
Other or combination	Uninjured	6	2,500	
Other or combination	AIS 1	26	4,748	
Other or combination	AIS 2	17	1,649	
Other or combination	AIS 3-6	23	1,857	
Other or combination	Total	72	10,754	

Table 41: Seat Performance and Injury Severity in Near-Side Impacts
(1990 NASS Front-Outboard Seats of Inspected Toved Cars)

Seat Performance	Injury Severity	Actual Cases	Weighted Number	Injured AIS 2+
No seat damage	Uninjured	201	123,783	
No seat damage	AIS 1	351	119,114	
No seat damage	AIS 2	87	16,520	
No seat damage	AIS 3-6	33	4,205	
No seat damage	Total	672	263,622	8%
Component broken	Uninjured	1	168	
Component broken	AIS 1	7	1,240	
Component broken	AIS 2	6	990	
Component broken	AIS 3-6	3	74	
Component broken	Total	17	2,472	43%
Deformed by occupant	Uninjured	2	460	
Deformed by occupant	AIS 1	15	2,832	
Deformed by occupant	AIS 2	6	1,669	
Deformed by occupant	AIS 3-6	4	777	
Deformed by occupant	Total	27	5,738	43%
Deformed by intrusion	Uninjured	10	9,146	
Deformed by intrusion	AIS 1	97	42,607	
Deformed by intrusion	AIS 2	50	8,041	
Deformed by intrusion	AIS 3-6	115	16,849	
Deformed by intrusion	Total	272	76,649	32%
Other or combination	Uninjured	0	0	
Other or combination	AIS 1	5	914	
Other or combination	AIS 2	4	339	
Other or combination	AIS 3-6	9	871	
Other or combination	Total	18	2,124	

Table 42: Seat Performance and Injury Severity in Far-Side Impacts
(1990 NASS Front-Outboard Seats of Inspected Toved Cars)

Seat [illegible]	Injury Severity	Actual Cases	Weighted Number	Injured AIS 2+
No seat damage	Uninjured	269	157,389	
No seat damage	AIS 1	392	115,394	
No seat damage	AIS 2	100	19,200	
No seat damage	AIS 3-6	45	4,597	
No seat damage	Total	806	296,580	8%
Component broken	Uninjured	4	1,904	
Component broken	AIS 1	7	1,549	
Component broken	AIS 2	4	326	
Component broken	AIS 3-6	4	448	
Component broken	Total	19	4,227	18%
Deformed by occupant	Uninjured	0	0	
Deformed by occupant	AIS 1	10	1,081	
Deformed by occupant	AIS 2	3	87	
Deformed by occupant	AIS 3-6	1	132	
Deformed by occupant	Total	14	1,300	17%
Deformed by intrusion	Uninjured	5	3,127	
Deformed by intrusion	AIS 1	23	6,630	
Deformed by intrusion	AIS 2	10	1,202	
Deformed by intrusion	AIS 3-6	18	2,861	
Deformed by intrusion	Total	56	13,821	29%
Other or combination	Uninjured	1	1,204	
Other or combination	AIS 1	7	670	
Other or combination	AIS 2	3	403	
Other or combination	AIS 3-6	3	221	
Other or combination	Total	14	2,498	

Table 43: Seat Performance and Injury Severity in Rear Impacts
(1990 NASS Front-Outboard Seats Of Inspected Towed Cars)

Seat Performance	Injury Severity	Actual Cases	Weighted Number	Injured AIS 2+
No seat damage	Uninjured	97	76,940	
No seat damage	AIS 1	186	60,713	
No seat damage	AIS 2	20	5,141	
No seat damage	AIS 3-6	3	238	
No seat damage	Total	306	143,031	4X
Component broken	Uninjured	20	6,359	
Component broken	AIS 1	53	14,786	
Component broken	AIS 2	1	766	
Component broken	AIS 3-6	3	127	
Component broken	Total	77	22,037	4x
Deformed by occupant	Uninjured	31	12,262	
Deformed by occupant	AIS 1	84	41,486	
Deformed by occupant	AIS 2	10	2,619	
Deformed by occupant	AIS 3-6	1	205	
Deformed by occupant	Total	126	56,578	52
Deformed by intrusion	Uninjured	0	0	
Deformed by intrusion	AIS 1	2	103	
Deformed by intrusion	AIS 2	0	0	
Deformed by intrusion	AIS 3-6	3	454	
Deformed by intrusion	Total	5	558	
Other or combination	Uninjured	5	477	
Other or combination	AIS 1	18	7,407	
Other or combination	AIS 2	3	433	
Other or combination	AIS 3-6	2	81	
Other or combination	Total	28	8,398	

The risk of moderate injury differed try vehicle impact type and seat performance, as summarized here from the data in Tables 39 to 43.

	Moderate Injury Rate			
	No Seat Damage	Component Broken	Deformed by: Occupant	Deformed by: Intrusion
Rollover	16 percent	27 percent	35 percent	67 percent
Front	10 percent	32 percent	34 percent	67 percent
Near-side	8 percent	43 percent	43 percent	32 percent
Far-side	8 percent	18 percent	17 percent	28 percent
Rear	4 percent	4 percent	5 percent	few data

The higher injury rate in damaged seats suggests that seat performance may be useful as a statistical control for crash severity (in analyzing other crashworthiness issues), but that it may be difficult to control statistically for crash severity to isolate the effect of seat damage on injury.

With additional years of detailed NASS seat performance data, it will be possible to compare injury consequences by seat damage type. The small number of cases currently available with these details on the automated file limit the comparisons that can be made. There were only 29 cases investigated in 1990 that met the following criteria: cars with nonrollover frontal damage and two front-outboard occupants (both a driver and right-front passenger), with the same belt use status for troth occupants (both were belted or neither was belted), and with one of these seats undamaged and the other with a single damage type (that is, with broken seat hardware, deformation from occupant impact, or intrusion-induced deformation -- excluding damage from multiple or unspecified causes). The data for these cases are summarized in Table 44.

Table 44: Seat Performance and Injury Severity in **Frontal** Impacts vith Either **Two Belted or** Tvo Unbelted **Front-Outboard Passengers and Exactly One of** these **Two** Seats Damaged (1990 **NASS** Inspected Toved Cars)

NMS Case Identifier	DV mph	Belt Used	Driver Age	Driver Seat Damage	Driver AIS	Driver Treat-ment	Right-Front Passenger Age	Right-Front Passenger Sert Damage	Right-Front Passenger AIS	Right-Front Passenger Treat-ment	Damage to Seat vith Worst Injury	Case Ratio Weight	Weighted Number for Subgroup of Serf Damage and Injury Outcome	
90-1-5-1	-	No	18	None*	6	Fatal			2	Hosp	None	437.12		
90-2-99-1	24	Yes	30	None	3	T&R	40 17	Bent* Bent	1	Disease	None	174.93		
90-44-122-2	-	Yes	29	None	2	Hosp	0	Bent*	2	Hosp	None	270.57		
90-72-145-2	23	No	37	None*					1	None	None	29.34		
90-74-198-1	-	No	18	None*	3	Hosp	17 5	Bent Bent*				127.80		
90-80-36-2	28	Yes	71	Bent	2	T&R Hosp	69	None	3	Hosp	None	20.93	1,061	82 %
90-10-23-1	-	No	21	Bent	2	TM	21	None*	1	T&R	Bent	139.67		
90-42-28-2	-	No	28	None	3	Hosp	70	Bent*	4	Fatal	Bent	11.12		
90-78-191-1	-	Yes	74	None*	3	Hosp	74	Bent	7	Fatal	Bent	79.42	230	18 %
90-4-107-1	-	No	22	Broken	2	T&R	18	None	3	Hosp	None	19.86		
90-75-2-1	-	No	26	None	2	T&R	26	Broken+	1	T&R	None	43.00		
90-75-4-1	-	No	25	None	2	Hosp	27	Broken+	1	T&R	None	128.99	192	11 %
90-1-14-2	18	No	19	None	1	T&R	16	Broken*	2	Hosp	Broken	580.84		
90-4-23-2	41	No	42	None	3	Hosp	36	Broken	S	Fatal	Broken	46.87		
90-12-7-1	44	No	17	Broken	3' •	Hosp	17	None	2	Hosp	Broken	41.65		
90-44-11-1	28	No	16	Broken	4	Hosp	15	None	2	Hosp	Broken	223.65		
90-45-54-1	.16	No	26	None	1	T&R	36	Broken*	2	Hosp	Broken	92.54		
90-45-115-I	-	No	28	None	1	T&R	23	Broken*	2	Hosp		97.26		
90-73-26-1	22	No	17	Broken*	2	T&R	17	None	1	T&R	Broken	126.64		
90-74-79-1	-	No	27	None	1	None	26	Broken*	2	T&R	Broken	124.96		
90-76-103-2	30	Yes	29	Broken*	3	Hosp	32	None*	7	T&R	Broken	148.43	1,483	89 %
90-13-95-1	21	No	35	Intrude	1	T&R	28	None	2	Hosp	None	129.23	129	31 %
90-4-5-2	-	No	48	Intrude	2	Hosp	48	None	2	T&R	Intrude	74.43		
90-7-110-1	20	No	25	Intrude*	2	Hosp	20	None	1	Unknovn	Intrude	52.31		
90-51-21-2	27	Yes	17	Intrude	3	Hosp	15'	None	1	T&R	Intrude	119.70		
90-74-144-2	-	No	33	None	4	Hosp	48	Intrude+	3	Fatal	Intrude	18.01		
90-77-76-1	-	No	23	None	1	T&R	25	Intrude	2	Hosp	Intrude	24.97	289	69 %
SC-1-120-1	54	Yes	27	None*	3	Fatal	5	Intrude	6	Fatal	Unclear	134.40		
50-51-63-2	29	No	51	Intrude	3	Hosp	69	None	3	Hosp	Unclear	278.91	413	-

Treatment:
- Fatal = Died as outcome of crash
- Disease = Died from other cause
- Hosp = Hospitalized
- T&R = Treated and released
- None = No treatmnt
- Unknovn = Treatment unknovn
- • indicates an occupant seated behind

Seat Damage:
- Bent = Deformed by occupant impact
- Broken = Damaged seat hardvare
- Intrude = Deformed by intrusion
- None = Undamaged

Injury: AIS 7 = Injured, severity unknown

The available data suggest that the relationship between seat damage and occupant injury may depend on the type of seat damage:

> When one seat was deformed by occupant loading and the other was undamaged, the more severe injury occurred in the ~damaged Seat in an estimated 82 percent of these crashes;
>
> When one seat had broken seat hardware and the other was ~damaged , the more severe injury occurred in the damaged Seat in 89 percent of these crashes;
>
> When one seat was deformed by intrusion into the passenger compartment and the other was ~damaged, the more severe injury occurred in the damaged seat in 69 percent of these crashes,

Compared to the experience in ~damaged seats, occupant-induced deformation (by any occupant -- not necessarily the occupant in that seat) was associated with lower injury severity, but seat breaking and intrusion-induced deformation were associated with more-severe injury in frontal impacts. There were too few data for *a* similar comparison for rear impacts, and the *experiences* in frontal and rear impacts may be quite different. This type of comparison (a variant of the matched-pairs comparison in Table 35) does not seem to be a useful method for exploring seat damage in side and rollover crashes , where the two occupants would experience very different crash forces.

There may *also* be important differences between the driver and right-front passenger experiences even in frontal and rear impacts that limit the validity of the comparison described by Table 44. For example, the seat design , specific damage location, structures surrounding the occupant, occupant characteristics, and rear-seat occupancy may differ to some extent. Table 44 shows that if one front-outboard seat was deformed by occupant loading and the other was undamaged: the right-front passenger seat was usually the one deformed, there was often a rear-seat occupant directly behind that seat, and the driver *was* usually the occupant who was more-seriously injured. As a result, it is not clear how well the differences in observed injury risk reflect the effect of seat damage on injury and to what extent seat damage reflect confounding factors and the effects of forces that cause both damage and injury.

FILE

RESEARCH **PLAN FOR**

SEATING SYSTEMS

Prepared by:

The National Highway Traffic Safety Administration

September 1992

3 JUL

RESEARCH PLAN FOR SEATING SYSTEMS

The following research efforts are planned to understand better current seating system properties and to attempt to resolve safety issues associated with occupant injuries. Phase I efforts are described below. The need for and contents of a Phase II research effort will be established after review of comments received in response to the request for public comments concerning Upgrade of Standard No. 207 and the results of Phase I efforts. It is currently envisioned that Phase II will include functional parameter measurements of production seats and construction and testing of an optimized seating system whose controlling design parameters are developed from exercise of the analytical model developed in Phase I. Phase II may also include test dummy upgrades to provide better human like responses to rearward head rotations and extensional loading of the neck as well as appropriate hip/femur rotation. Subsequent efforts may be devoted to development of compliance test procedures and establishment of measurement parameters and their tolerable limits.

PHASE I

ANALYTICAL MODELING OF OCCUPANT SEATING/RESTRAINT SYSTEMS

The purpose of this research is to develop and validate models which can be used to analyze the performance of baseline, modified baseline, and integrated seating systems. The resulting products will provide the capability of analyzing a large variety of questions regarding the forces, deformations, and occupant protection performance of seats which contain different levels of seat strength, head restraint and system geometries, and other occupant restraint features and thereby may provide a means to reduce the number of tests required to achieve better seat designs.

The models shall be validated in frontal and rear impacts for two physical seats: (1) a baseline seat which meets all current standards, and (2) an integrated seat which includes all three belt attachment points. The model should then be applicable to both types of seat designs, including seats with folding seat backs.

STRUCTURAL ANALYSIS OF SEATING AND RESTRAINT SYSTEMS

The objective of this task is to determine the characteristics of the physical system to be modeled, and to develop data for the model by physical measurements, and the conduction of static and dynamic tests.

A seat model shall be developed which when input with crash loadings of front and rear impacts will faithfully predict the following:

Loads reacted by the seat track and anchorages
Seat and seat back displacement and loads on seat back locking device

Safety belt **loads**, including those induced by pntensiuning
Occupant chest, head, neck and pelvic loads, displacement and acceleration
Occupant kinematics versus seat height and head restraint position

In modeling the seat anchorage loading and seat displacements, at **a** minimum the following **load** sources shall be considered:

Seat Inertia
Anti-submarining seat reaction **(occupant loading)**
Occupant seat **back and bead restraint luading** during rearward seat **loading**
Knee loading **from** restrained and **unrestrained** rear seat occupants
Lower anchorage(s) fur seat **mounted lap belt**
Upper anchorage fur seat **mounted** shoulder belt
Rigid and nonrigid **floor support** fur the seating system

Static and dynamic tests shall be conducted to assess the magnitude of each of the load sources. To accomplish this a static test rig, a sled buck and a test seat shall be designed and constructed. These shall accommodate the measurement of forces transmitted to the seat anchorage, scat back and head restraint and the measurement of resulting deformations.

Two seats shall be selected fur model validaticm: a baseline seat and an integrated seat. Physical measurements shall be made and static and dynamic tests **of the two seats and their** components shall be made **to** evaluate their mechanical **and** damping **properties. Tbe** physical measurements will include dimensions, centers of gravity, and mass **moments** of inertia of major scat, bead **restraint,** and back **components.** In **order to conduct** the static **tests, a test rig shall be constructed which will permit the application of loads to the seat,** head restraint, and seat back, and provide fur the measurement **of** the resulting **deformations** and reactions at anchorage and hinge points. Static **load** testing shall be conducted which simulate luading **sources** in **addition to** the seat inertia, e.g., **occupant loads,** belt **anchorage loads.**

Using the results of the static tests, an instrumented seat and sled buck for dynamic testing shall **be** made. **Both frontal** and **rear** car crash sled **simulations shall** be **conducted** employing **the 50th percentile Hybrid III dummy. These sled tests shall investigate the seat loading, load paths within the seat, belt anchorage loads, and seat anchorage loading. The frontal crash test series shall measure** the **influence of** anti-sub**marining seat pan configurations and belt anchorage locations on the seat. The rear impact tests shall evaluate the influence of seat back stiffness and seat back energy absorption on seat loads. Additional rear impact sled tests shall be conducted to evaluate the influence of head restraint designs on dummy neck responses.**

Analysis of the test data shall be performed to establish appropriate input data to the MADYMO simulation model.

DEVELOPMENT AND VALIDATION OF MODEL

A literature review on seating system models will be an early effort. If no suitable models are found, and no suitable models are made available by responders to the request fur comments from the public regarding Upgrade of Standard No. 207, the following effort will be implemented.

The objective is to develop a MADYMO based model which has been validated for predicting occupant, seat, and restraint system response in frontal and rear impacts. The validation will be conducted for two seat/restraint systems which represent a range of expected performance. The seat/restraint systems shall be selected on the basis of the exploratory static loading and sled tests conducted earlier in the program.

At present, the MADYMO program incorporates only membrane type finite elements which are not suitable for modeling of seat structure. Therefore, the structures in the seat back and seat will be three dimensionally represented as multiple lumped masses connected by joints, including at a minimum, one at the seat to seat back connection, one at mid height of the seat back, and one at the head restraint attachment. These lumped masses and joints must be suitable for modeling folding seat backs, varied seat back stiffness as function of height location, and influence of head restraint stiffness. Springs and dampers will be incorporated to model the structural response. The properties of the springs and dampers will be determined from the static and dynamic testing conducted earlier.

The seat, seat back, dummy, and restraint systems will be modeled using the presently available MADYMO program and the resulting model exercised on the NHTSA VAX computer.

A series of sled tests will be conducted for model validation. These tests will include frontal and rear crash simulations and shall employ a 50th percentile Hybrid III dummy. In order to insure the accuracy of the validation data, each test will be replicated. The resulting tests will form the basis for the model validation.

The contractor shall correct the seat representation as required to achieve agreement between the model and the primary validation conditions.

The results will be documented in an interim report, and demonstrated to NHTSA personnel, using the VAX computer.

EXTENSION OF THE MODEL TO OTHER DUMMY SIZES AND CRASH SPEEDS

Based on the quality of results achieved in the prior efforts, a decision shall be made as to whether further model improvement and validation efforts are justified. Such additional validation would include front and rear crash sled tests at higher speeds and would add tests with 5th percentile female and 95th percentile male Hybrid III dummies. If it is decided to perform this additional work the results would be used to validate the model for higher speeds and a range of dummy occupant sizes. Further efforts may also be expended tu correct the Seat representation as required to achieve agreement between the mudel and the validation conditions.

The results will be documented in a final report, and demonstrated to NHTSA personnel, using the VAX computer.

REAL-WORLD COLLISION DATA ANALYSES

There were 1,156 damaged car seats (among occupied front-outboard seats) reported in the 1990 NASS data. These were the only automated data available that distinguished seat bending from seat breaking when the report "Seat Damage and Occupant Injury in Passenger Car Towaway Crashes" was recently prepared by Susan C. Partyka. The complete 1991 NASS data, which are now available, approximately doubles the data base readily available for a statistical analysis. The data analysis will now be performed employing the enlarged automated data base. A special effort will be made to distinguish seat bending influence on occupant injury from tbat of seat breaking using this data source which provides such identification within the damaged seat category.

PROGRAM OUTPUTS

Collision Data Report	Approximately three months
Final Report	Approximately one year

89-20-N03-001

U.S.Department
of Transportation

National Highway
Traffic Safety
Administration

UPGRADE SEATING

FILE

Patents, Literature Search, and Accident Analysis

Kennerly Digges
John Morris

University of Virginia
Department of Mechanical and Aerospace Engineering
Charlottesville, VA 22901

Prepared for:

National Highway Traffic Safety Administration
Research and Development
Office of Crashworthiness Research
400 Seventh St., S.W.
Washington, D.C. 20590

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16. Abstract

This report examines opportunities for reducing highway casualties through improvements in air bags, belt systems, interior padding, seating systems, and pre-crash sensing. The focus of this report is on seating systems; a summary of the search of the literature, patents, and regulations related to seating is provided. In addition, recent accident data analyses related to seat performance were reviewed, and the results summarized. A total of 45 NASS cases were reviewed to evaluate seat performance in real crashes. The results are included in this report. Finally, recent trends in seat design are reported.

17. Key Words	18. Distribution Statement
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METRIC CONVERSION FACTORS

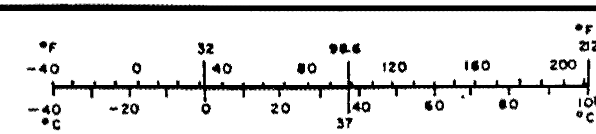
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.99	liters	l
gal	gallons	3.1	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



U.S.Department
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**National Highway
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UPGRADE SEATING

Patents, Literature Search, and Accident Analysis

Kennerly Digges
John Morris

University of Virginia
Department of Mechanical and Aerospace Engineering
Charlottesville, VA 22901

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Washington, D.C. 20590

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INTRODUCTION

This report summarizes the interim results of a research project entitled, "*Upgrade Seat and Occupant Protection Systems*". The research examines opportunities for reducing highway casualties through improvements in air bags, belt systems, interior padding, seating systems, and pre-crash sensing. The focus of this report is on seating systems. The report provides a summary of the search of the literature, patents, and regulations related to seating. In addition, recent accident data analyses related to seat performance were reviewed, and the results summarized. A total of 45 NASS cases were reviewed to evaluate seat performance in real crashes. The results are included in this report. Finally, recent trends in seat design are reported.

A recent trend in seat design is the incorporation of the safety belt anchorages on the seat structure. In many new cars, the anchorage for the lap belt buckle is on the seat structure. Some have both lower belt anchorages attached to the seat. Seat manufacturers are now developing designs for all three anchorages to be fastened to the seat. These changes, which integrate the seat and restraint system, are anticipated to have a very positive effect on restraint comfort, use rate, and safety.

SEATING SYSTEMS LITERATURE AND PATENTS

Historical Perspective of the Integrated Seat Concept

Today, the vehicle seat is generally recognized as a fundamental portion of the total occupant crash protection system. However, the design of belt restraint systems and seating systems have largely progressed independently. In recent years, numerous technological innovations have been incorporated into production seats and restraint systems to improve the combined performance.

Our search of patents and literature indicates that many of the currently emerging concepts and innovations were thought of long ago by engineers and inventors. It is still constructive to examine some of these creative ideas in the light of today's understanding of biomechanics, the accident environment, and available technology.

The concept of an integrated seat and restraint system has been around as long as the automobile. In early automobiles, the principal function of lap belts was to keep the occupants from being ejected from their vehicles when driving on bumpy roads. In 1903,

Levau of France patented an integrated seat with a lap belt and two shoulder belts. The upper anchorages for the shoulder belts were attached to the seat back. The belts were routed diagonally across the chest, forming an "X". A sketch is shown in Figure 1 (Levau 1903).

In 1967, this integrated seat-belt concept was incorporated by Republic Aviation Div., Fairchild-Hiller Corp. in the New York Safety Sedan. This vehicle was only a "paper" concept car. Figure 2 shows the design. However, during the same period, General Motors, Ford, and Chrysler all showed seat-integrated restraints in their concept cars named "Astro 1", "Techna", and "300X", respectively.

In his 1969 paper, Snyder offers the following comments regarding passenger seats which integrate the "X" type shoulder belt system:

> *The seat integrated system would allow nearly correct belt angles and optimum placement for all occupants, since the system would be independent of seat movement, and limitations of various package designs. The unsightly gaggle of straps would disappear, and with improved lateral flaring 'in bucket seating, greater side impact protection could be provided. Balanced against this, however, are new problems. Such seats must be constructed to contain inertia reels, retractors, or other devices, yet be built strong enough to protect against 40 G loads. Because the shoulder harness would retract into the seat back above the shoulder level, the higher CG, combined with possible rear-passenger loading, during forward impact would require considerable structural strengthening of presently available seats. Even with modem materials, so that weight is no longer a problem, it has been estimated that such seats might add considerably to car cost. .... Nevertheless, it seems probable that this is one direction in which restraints will evolve."*

Some of the earliest automotive safety research sponsored by the federal government was directed to improve seating systems. An early program at UCLA, sponsored by the Public Health Service, was summarized by Severy, et al. in a 110 page SAE paper, *"Backrest and Head Restraint Design for Rear-Collision Protection"*, SAE 680079. The conclusions of this paper are included in Appendix A. The authors conclude that elastic rebound from seat backs increases the chance of multiple impact injuries. However, they conclude that increasing the seat rigidity reduces rebound. They postulate that rebound energy comes principally from the elastic deformation of the seatback metal frame. The implication that there is the need for a stiff frame with energy absorption built into the padding and springs.

Severy applied his experience from the UCLA program to design an integrated seat for

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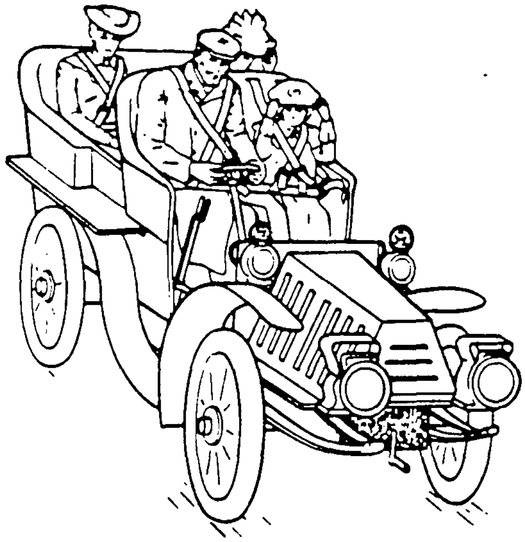
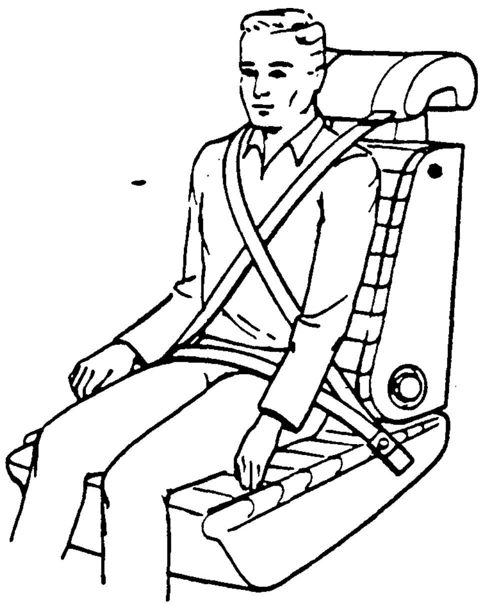


- Integrated full body restraint system conceived and patented by Leveau of France in 1903

Figure 1



- Final version of New York safety sedan design by Republic Aviation Div., Fairchild-Hiller Corp.

Figure 2

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the Liberty Mutual Safety Car. The resulting design was constructed and crash tested. The design was a capsule seat with integrated double shoulder belt and lap belt restraints, a head restraint, and side wings for side impact protection. The seat was mounted on a pedestal base, which was designed to flex at the floor pan, thereby mitigating impact energy. The design is shown in an SAE paper (Severy 67). A sketch of the design is shown in Figure 3.

Later studies, funded by the Federal Highway Administration, were awarded to Cornell Aeronautical Laboratory and HSRI. The final report, "Integrated Seat and Occupant Restraint System Performance", was published in 1967. These studies examined modeling, injury criteria, and cost benefits analysis for integrated seat concepts. Recommendations were made for elaborate follow-on research. In follow-on research, HSRI designed an integrated safety seat which employed two shoulder belts and a lap belt which formed an "A" configuration. In this design, the single upper anchorage was attached to the roof. The HSRI design is described by Melvin (72), and is shown in Figure 4.

The HSRI seat was further developed and tested in a NHTSA research program to develop a deployable head restraint. The results of this research are reported by Melvin (72) and Hilyard (73). The anchors demonstrated effective protection in severe rear-end collisions at vehicle-to-vehicle closing speeds of 80 mph with 40 G peak crush structures. Both deployable and non-deployable head restraints were designed and tested. The authors stressed the importance of matching head restraints and seat back structure. They also found benefits in minimizing elastic energy storage in the seatback by utilizing a basically rigid, load carrying seat structure.

Rear impact tests with dummies and cadavers were reported by Hu (78 and 80). In these NHTSA sponsored programs, sixteen dummy and nine cadaver tests were documented. The cadaver tests were at a delta v of 16 to 17 mph. Five tests incorporated deflecting seatbacks and six had rigid seatbacks. Neck fractures of AIS 3 level were observed on all but two specimens, the remaining were uninjured. The differences in the specimens and test variables for the cadaver tests were such that insufficient data was developed to draw conclusions on the relative risk of neck injury for deflecting versus rigid seats.

Patents of Interest

A search of patents suggests several concepts which may have application to improved seating design. Although many of the patents are not practical, the ideas and objectives are often interesting, and consequently, may form a basis for practical safety systems. Selected patents will be summarized in the sections to follow.

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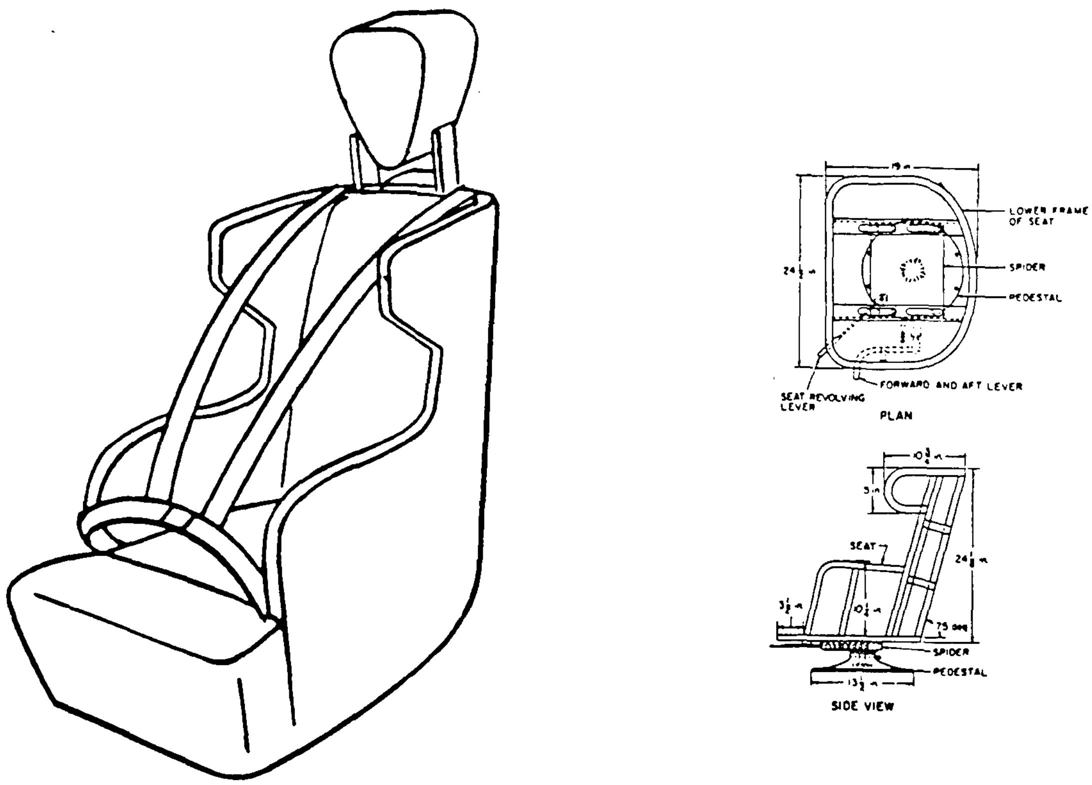
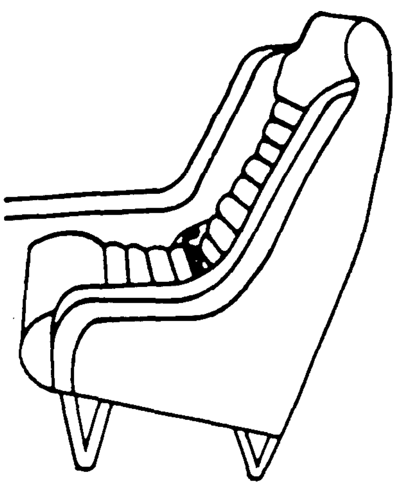
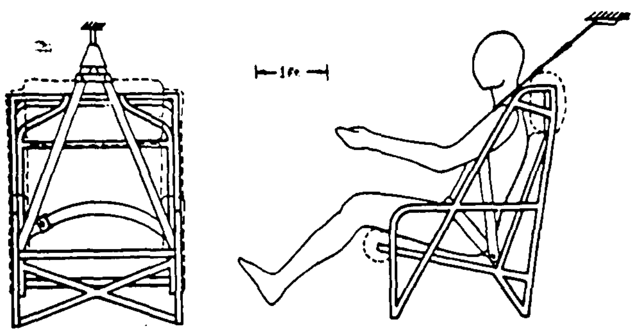


· Liberty Mutual capsule seat design incorporated an integrated harness, seat support and side flaring to protect against side collisions

Figure 3





(b) Seat Frame

. THE HSRI INTEGRATED SAFETY SEAT (ISS)

(a) With Upholstery

Figure 4

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The Cox Company, in England, was active in the early 60's in designing safety seats. Babbs (63), and Hilton (66) describe their research seats. Their 1963 design incorporates an integrated four point belt system. The design is shown in Figure 5.

In 1957, Pinkel and Rosenberg of NACA (now NASA) Lewis Research Center, proposed an energy absorbing pedestal for the seat mounting element. Crash energy is absorbed by plastic deformation of corrugated cylinders which make up the base. The seat includes an integrated belt restraint system. The plastic deformation in a rear crash is shown in Figure 6 (Pinkel 57).

A number of patents deal with air bags, rather than or in addition to belts integrated into seats.

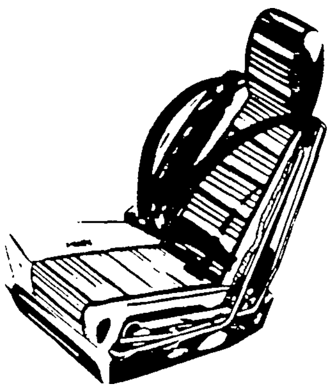
Nate Pulling of Liberty Mutual, in 1975, patented air bag restraints integrated into a capsule seat. The air bags deployed from each side and restrained the abdomen/pelvic area to the seat. The patent is summarized in Figure 7.

Surace of Alfa Romeo patented an inflatable head protector, which is shown in Figure 8. A seatback integrated air bag for side impact protection is shown in Figure 9. For rear protection, Daimler Benz has patented an air bag which deploys from the head restraint as shown in Figure 10.

Patents also exist for air bags which deploy from the seatback and protect rear seat occupants. Indeed, NHTSA's early air bag research envisioned air bag protection for both front and rear occupants. In January 1992, Allen Breed, speaking before the Automotive News Congress, predicted rear seat air bags as the next significant safety feature in luxury cars. Possibly, the Bertrand patent, sketched in Figure 11, is within the realm of possibility.

A Daimler Benz patent for seats with internal air pressure is described in Figure 12. This patent is primarily oriented to comfort, however, it may also have applications in the control of injury from impact and rebound.

A number of inventors have suggested seats designed so that the front of the seat tilts and rotates upward during a crash. An active design, circa 1964, is shown in Figure 13. A variety of active and passive designs are shown in Figure 14. The most recent entry is by Topsource, which claims to have sold their tilting seat design to Chrysler for a future production vehicle. The postulated benefit of the titling seat is to reduce submarining.



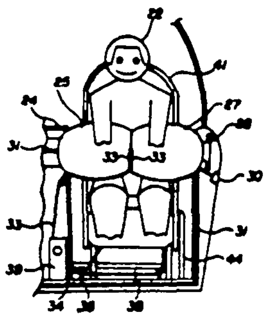
– THE COX SAFETY SEAT (1963)

Figure 5

Experimental D·plex Seat: *Impact* From Rear

Figure 6

3,981,518
VEHICLE RESTRAINT SYSTEM
Nathaniel H. Pulling, East Orleans, Mass., assignor to Liberty Mutual Insurance Company, Boston, Mass.
Filed May 5, 1975, Ser. No. 574,285
Int. Cl.² B60R 21/08
U.S. Cl. 280—730 6 Claims



1. A safety system comprising:

a vehicle for providing human transportation, said vehicle comprising a front end that leads said vehicle during normal movement thereof;
seating means including a seat for accommodating a passenger of said vehicle, said seat comprising a substantially horizontal base portion for supporting the buttocks of the passenger and a substantially vertical back rest portion for supporting the back thereof;
inflatable air cushion means comprising a pair of independently inflatable bags one disposed on each side of said seat so as to be forced upon inflation into mutually engaging positions adjacent the abdomen of the passenger;
collision responsive detector means for simultaneously inflating said bags in response to detection of a collision or impending collision of said vehicle;
lateral support means for restraining the self-induced lateral thrust produced by engagement of said inflated bags, said support means comprising a support member on each side of said seat; and
a flexible, non-elastic restraint means secured to each of said bags so as to restrain upward movement thereof, one of said restraint means having one end secured to the mutually engaged surface of one of said bags and the other said restraint means having one end secured to the mutually engaged surface of the other bag, the opposite ends of said restraint means being secured to said vehicle

Figure 7

3,953,049
INFLATABLE HEAD PROTECTOR
Filippo Surace, Milan, and Marco Garetti, Mariano Comense (Como), both of Italy, assignors to Alfa Romeo S.p.A., Milan, Italy
Filed Mar. 7, 1974, Ser. No. 449,211
Claims priority, application Italy, Mar. 8, 1973, 21333/73
Int. Cl.² B60R 21/08
U.S. Cl. 280—730 12 Claims

1. A device for the protection of the head on an occupant in a motor vehicle in the case of impact forces on the vehicle, said device comprising a protective strip having an extended operative position and a retracted inoperative position, said strip including a plurality of inflatable members, a casing retaining said strip folded on itself in said retracted position, said strip in said inoperative position extending along a substantially U-shaped line and having opposite ends with means attaching said ends to a structure which is integral with the vehicle at two points situated on a horizontal axis extending transversely of the vehicle at a position behind and on opposite sides of the head of an occupant seated in said vehicle for unfurling said strip in its operative position to extend essentially along a surface generated by rotation of said U-shaped line around said axis, said inflatable members of the strip including lateral sectors which in operative inflated position are disposed in front of the head of the occupant to be contacted thereby and produce tensile stresses in said sectors passing substantially through said axis, the line of action of the resultant of said tensile stresses substantially coinciding with the center of gravity of the occupant's head, and means responsive to a preselected deceleration magnitude of the vehicle for inflating said inflatable members to expel said strip from said folded inoperative position in said casing to said unfurled operative position, said inflatable members during inflation undergoing rapid transition to the inflated condition while the strip is restrained at said ends.

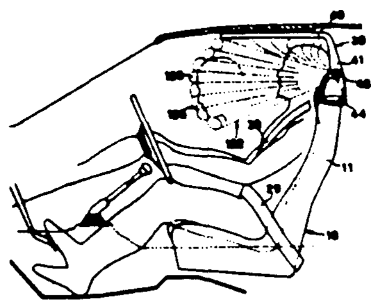


Figure 8

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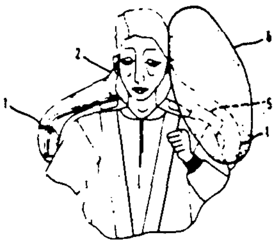
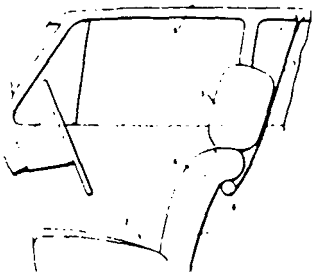
4,946,191
MOTOR VEHICLE SEAT WITH A BACK REST AND AIR BAG ASSEMBLY
Peter-Ulrich Putsch, Rockenhausen, Fed. Rep. of Germany, assignor to Keiper Recaro GmbH & Co., Fed. Rep. of Germany
Filed Dec. 8, 1988, Ser. No. 281,230
Claims priority, application Fed. Rep. of Germany, Dec. 9, 1987, 3741637
Int. Cl.[5] B60R 21/18, 21/22
U.S. Cl. 280—730 10 Claims



1. Vehicle seat, particularly a motor vehicle seat for supporting a vehicle user, comprising a back rest having a head rest for supporting only a back side of the user's head, an area supporting the shoulders of the user, and having at least one forwardly projecting side wing in the area supporting the shoulders of the seat user but not laterally of the user's head, wherein the vision of the user is unobstructed, said side wing having an upper surface; said side wing including at least one recess positioned in said upper surface, in which an inflatable air bag is located, whereby said air bag, in the inflated condition of said air bag, forms a support laterally adjacent the head of the seat user.

Figure 9

3,703,313
SEAT, ESPECIALLY FOR MOTOR VEHICLES
Gerhard Schlesterl, Stuttgart, and Helmut Wulf, Neilingen, both of Germany, assignors to Daimler-Benz Aktiengesellschaft, Stuttgart, Germany
Filed July 29, 1971, Ser. No. 167,217
Claims priority, application Germany, July 39, 1970, P 20 37565.9
Int. Cl. A47c 7/36
US. Cl. 297—391 5 Claims



A seat, especially for motor vehicles, in which a gas cushion acting as headrest and automatically inflatable in case of an accident is arranged at the backrest of the seat; at least one belt is arranged behind the gas cushion for absorbing the rebound forces of the head of the passenger impinging against the gas cushion whereby the belt is arranged, on the one hand, within the area of the vehicle roof, and on the other, at the seat.

Figure 10

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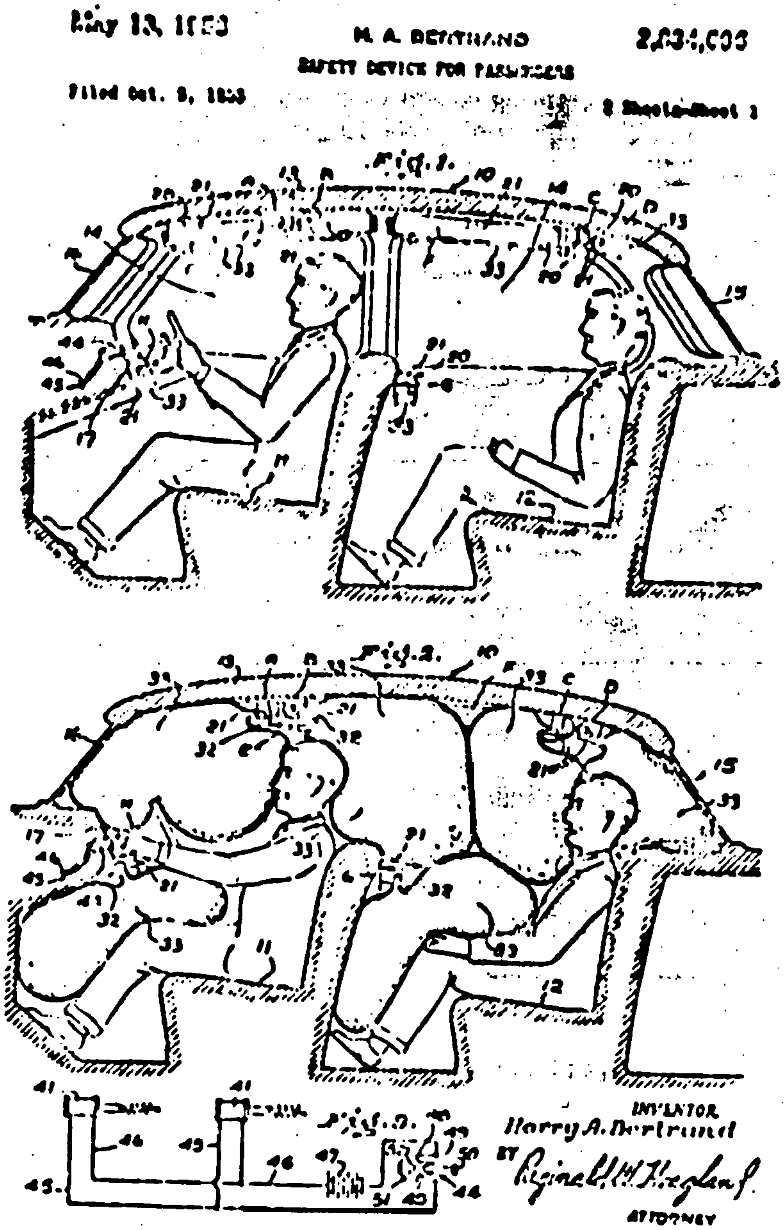

Air Bag Restraint Syrtem

Figure 11

4,497,517
MOTOR VEHICLE SEAT

Günter Gmeiner, Sindelfingen; Hermann Möller, Aidlingen; Rudolf Andres, Sindelfingen, and Eberhard Faust, Stuttgart-Degerloch, all of Fed. Rep. of Germany, assignors to Daimler-Benz Aktiengesellschaft, Fed. Rep. of Germany

Filed Jun. 30, 1982, Ser. No. 393,597
Claims priority, application Fed. Rep. of Germany, Jun. 30, 1981, 3125588
Int. Cl.³ A47C 7/02
U.S. Cl. 297—231 7 Claims

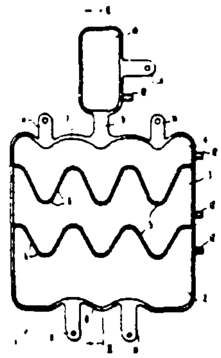

Figure 12

1. A seat cushion adapted to be concealed within a backrest [illegible] motorvehicleseat, comprising at least two superimposed separately inflatable chamber means for forming a support for a spinal column of a user of the seat cushion, continuous connecting rib means extending generally transversely of the seat cushion between adjoining chamber means of said at least two superimposed chambers, said connecting rib means disposed so as to follow an undulating path such that adjoining walls of adjoining chamber means of said at least two superimposed chamber means form an area of tooth-like meshing, said area being a transition area wherein adjoining chamber means of said at least two superimposed chamber means inflated to [illegible] hardnesses are less apparent [illegible] user supported thereby.

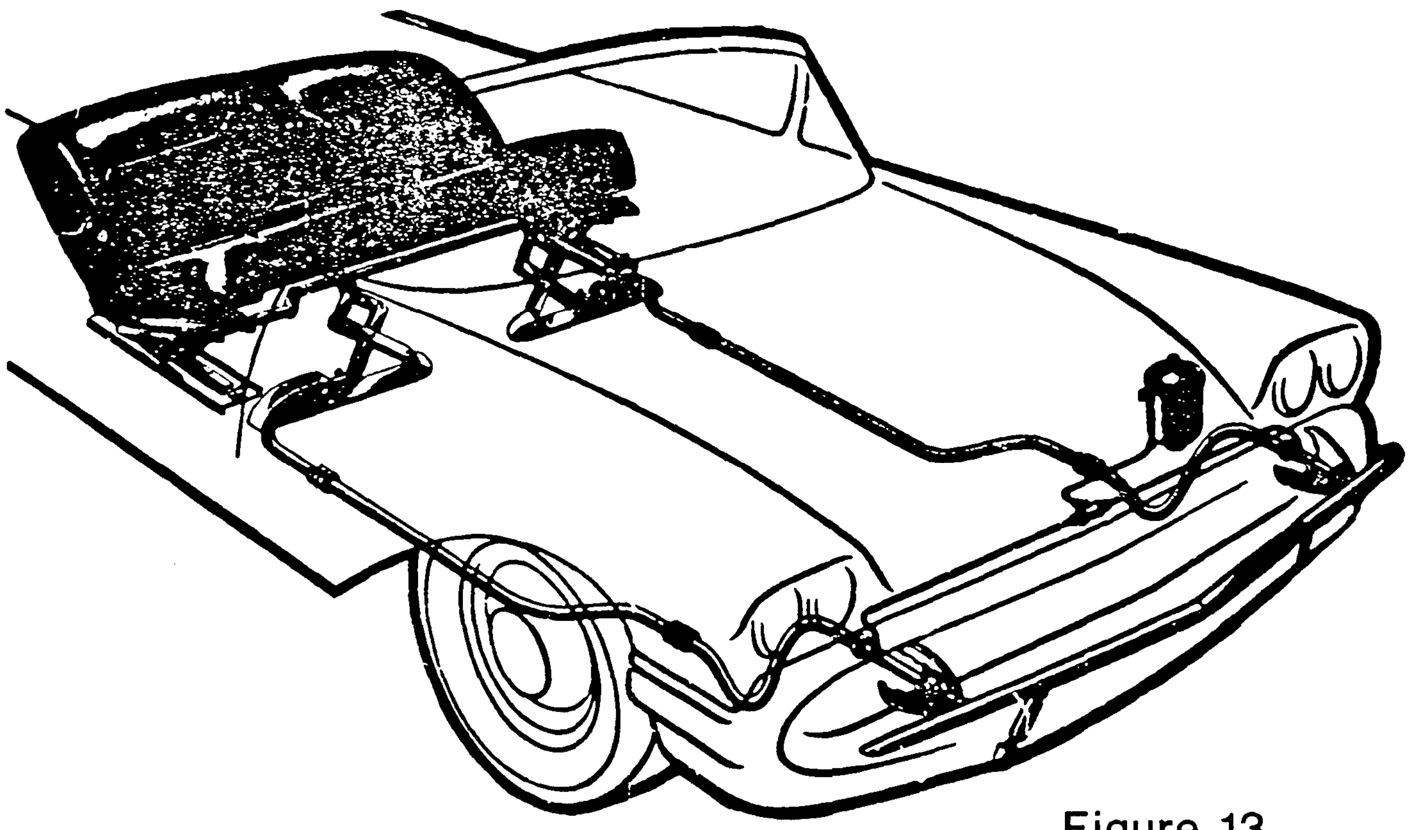

Figure 13

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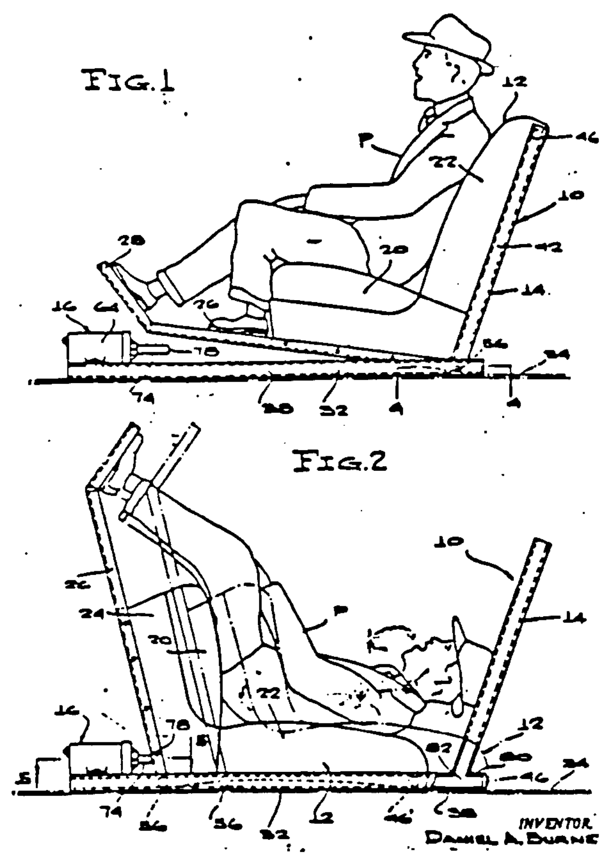
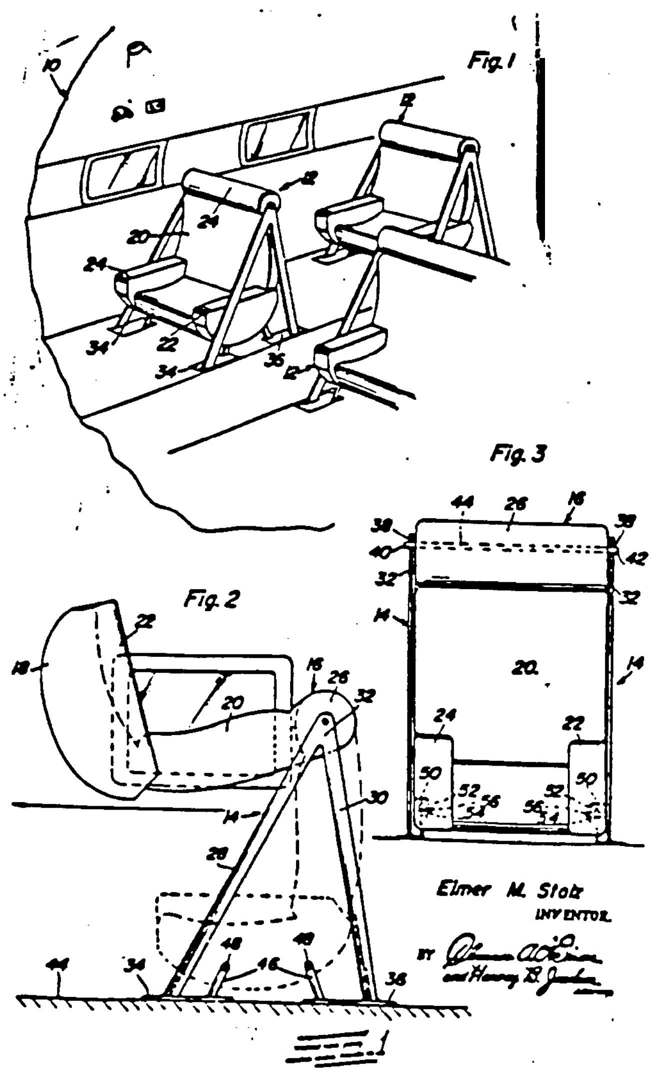
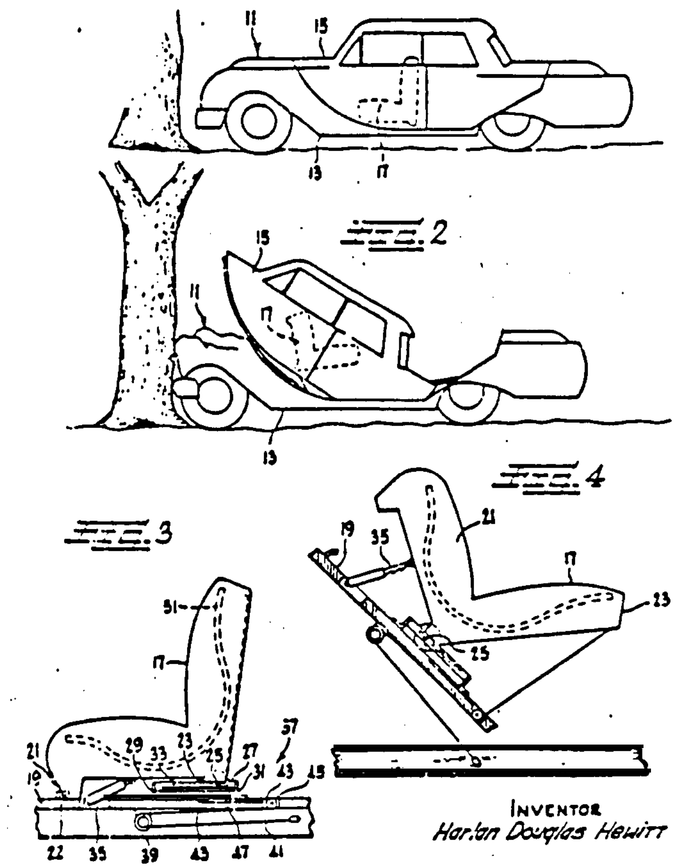
• Active Scat Tilt - Protect-0-Matic Version

MOVING SEAT ART







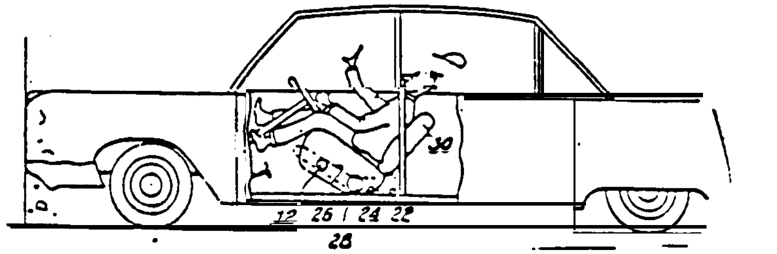


Figure 14

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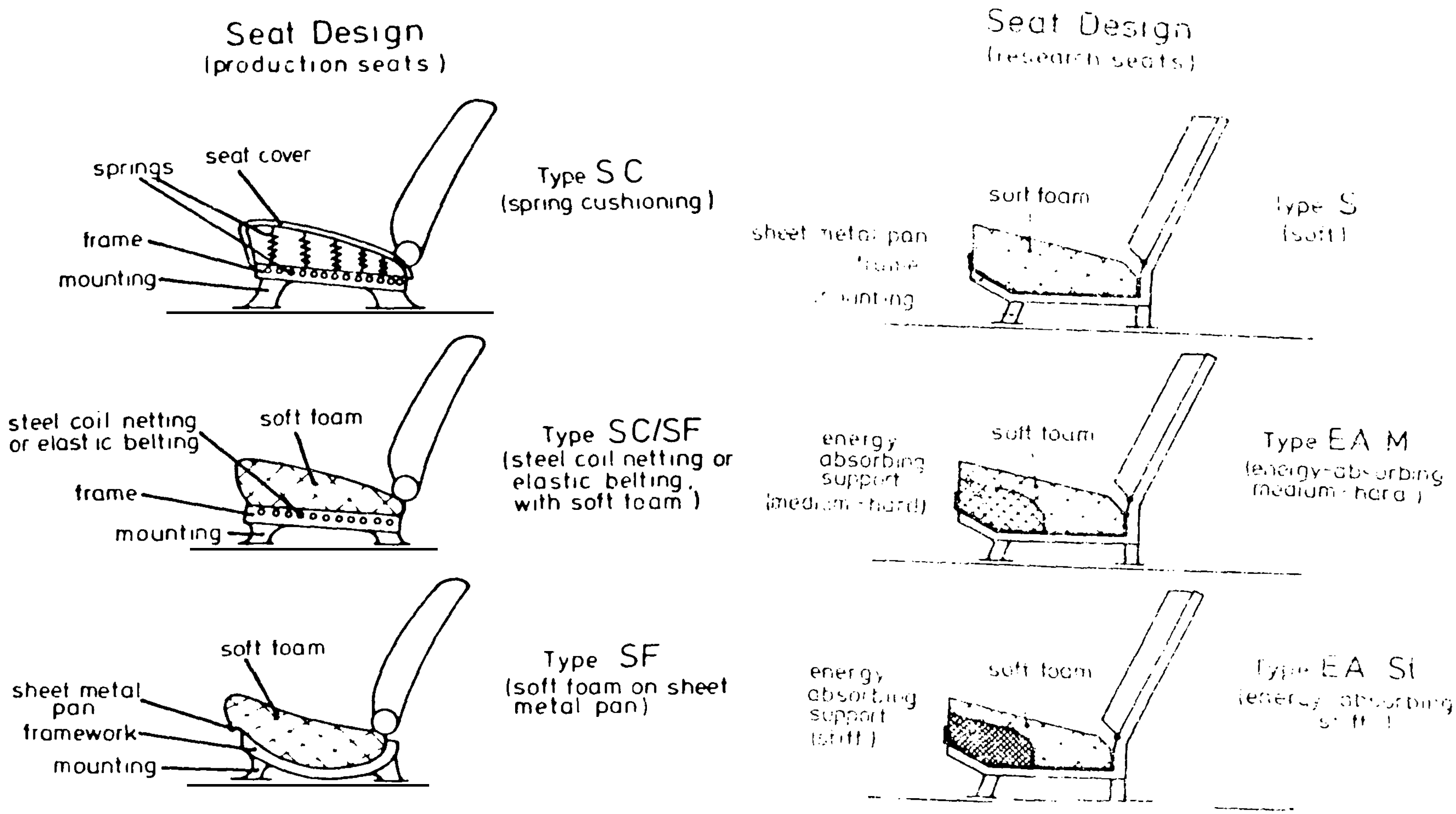
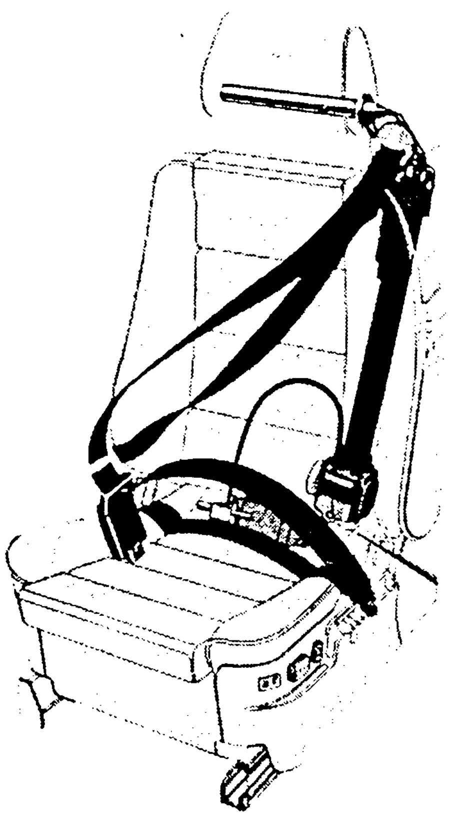

Seat Design
(production seats)
springs
seat cover
frame
mounting
Type SC
(spring cushioning)
steel coil netting or elastic belting
soft foam
frame
mounting
Type SC/SF
(steel coil netting or elastic belting, with soft foam)
soft foam
sheet metal pan
framework
mounting
Type SF
(soft foam on sheet metal pan)
Seat Design
(research seats)
soft foam
sheet metal pan
Type S
energy absorbing support (medium-hard)
soft foam
Type EA M
(energy-absorbing medium-hard)
energy absorbing support
soft foam
Type EA St

Figure 15



All belt anchorage points move with the seat
- optimum belt geometry in all seat positions

Automatic height adjustment of head restraint and seat belt outlet
- eliminates incorrect adjustment

Clamping device at belt outlet
- reduces occupant forward displacement

Defined energy absorption
- minimizes occupant load

High-strenght frame structure
- improves protection in side impacts and rear end collisions

Seat shell with integrated ramp
- prevents "submarining"

SBS safety features

Figure 16

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There are, however, other means for designing seats for controlling submarining. Seats with contoured stiffness to resist forward pelvic motion have been advertised by VW and Volvo for a number of years. A 1979 paper by Adomeit shows the concept, as does Figure 15.

Recent Developments

In recent years, research has rediscovered the integrated seat. Daimler Benz and BMW both offer integrated seats in production cars. In the case of Mercedes Benz, the integrated seat solves unfavorable belt geometry problems which exist in a convertible.

The BMW seat is described in a paper by Haberl (89). The design and features are summarized in Figure 16. Test results produced dramatic injury reductions, ranging from 25% to 57% in HIC, Chest G's, and shoulder belt loads, when compared to baseline 50 kph tests. Test results are reported for a 50% and a 95% dummy. A particularly interesting feature of the seat design is the force limiting feature, which is reported to be accomplished by deformation of the seat back at high belt loads.

At the 1991 ESV Conference, Renault contributed a summary of their recent research on a seat with an integral belt restraint (Foret-Bruno, 1991). In this paper, the authors desire to strengthen the seat for an integrated restraint without increasing the risk of cervical injury in rear impacts. A previous Renault Paper (Thomas 1982) had postulated that seat breakage was more effective than a head restraint. In the 1982 paper, the head restraint effectiveness was found to be less than 10%. In the 1991 paper, the effectiveness was found to be 33%. The effectiveness was found to increase as seats became stronger and broke at higher forces. Based on testing with dummies and one cadaver, the authors recommended head rest specifications. They state that the head rest, when placed against the back of the head, should withstand the following: longitudinal force of 187 lbs; vertical force of 56 lbs.; torque of 620 in-lb. The authors state that better overall protection should result from the integrated seat.

Several recent papers from Collision Safety Engineering, Inc. provide useful data, references, and technical arguments for the status quo. Strother (87) provides a summary of seat performance in rear impact tests. The resulting tables are reproduced in Appendix B. Warner (91) presents data on the static tests of seats for cars ranging from model year 1964 through 1988. This data is also included in Appendix B. Strother (91) presents an analysis of field accident studies and sled tests to show that injuries addressed by stiffening the seatback are a minimal portion of the total injuries. These three papers provide well articulated, legal defense positions for not increasing seatback stiffness. They argue that

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increasing seatback stiffness would increase injury exposure due to ramping, rebound, out-of-position occupants, flailing of lower extremities, and non-contact injuries.

At the February, 1992, SAE Annual Meeting, four automotive seat manufacturers displayed integrated seat concepts. These concept seats are shown in Figures 17 through 20. Figure 17 is the integrated seat by Bertrand Fauer. This company also produces the integrated seat now in use by BMW. Representatives stated that in Europe, all manufacturers are moving to place both lower belt anchorages on the seat. The next logical step is the integrated seat. Figure 18 is the seat shown by Johnson Controls. Technical data indicated its weight at 42.6 lbs. It is designed for a 3200 lb upper belt load. Seats by Lear and by Douglas & Lomason Company are shown in Figures 19 and 20. No technical data was available for these integrated seats.

Summary

It is evident from the history of seating designed to improve safety that very creative ideas have been considered. The focus on the air bag and passive restraints during the 70's and 80's may have delayed the implementation of the early ideas for seating design. However, it now appears that several technologies are about to emerge. First, the integration of the lower inboard anchorage point with the seat is becoming a standard practice. Second, the lower outboard anchorage point is also being located on the seat in newer cars. Third, the upper anchorage point is being integrated into the seat and/or head rest on some Mercedes' and BMW's. Renault indicates that it is doing research to follow this European lead. Fourth, rear seat air bags are being developed by Breed. These bags would most likely deploy from the back of the front seat. Finally, automotive seat manufacturers are actively developing integrated seats as new products.

The last three items in the above list which are being developed will require stronger seats. Data from Warner shows that seat strength has not changed significantly in the past 20 years. The concerns of neck loading, ramping, out-of-position occupants, limb flailing, and rebound will have to be addressed for these stronger seats. The neck problems will demand adequate head restraints. The rebound problems appear to be associated with the storage and release of excessive elastic energy in the seat and inadequate performance of existing belt systems.

The rebound problem need not be addressed in terms of existing belt restraint, but rather in terms of an integrated belt restraint. If the seat is to be strengthened, an integrated restraint should be part of the equation. For an integrated seat and restraint system, the

Figure 17

Figure 18

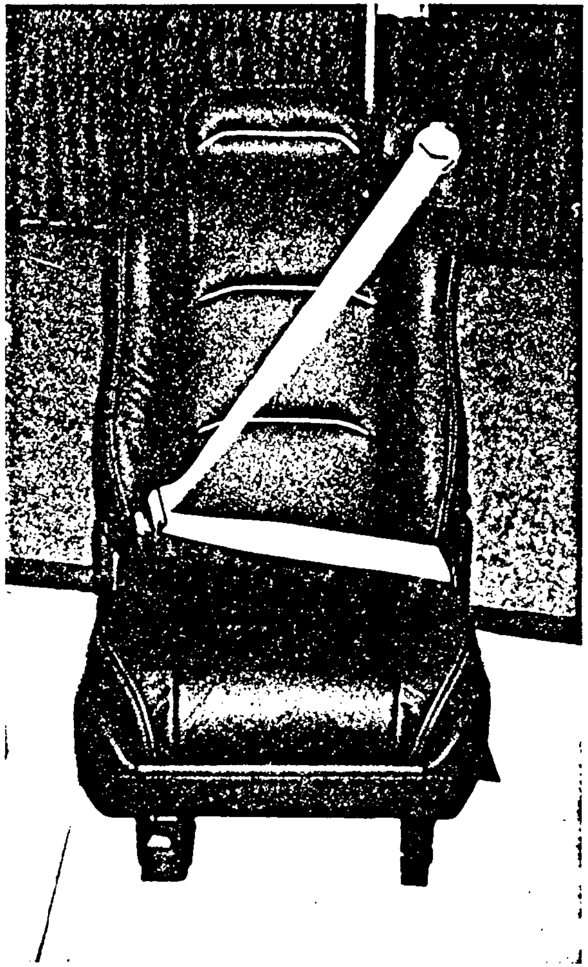

Figure 19

Figure 20

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optimum loading for both the occupant and the seat back is likely to be a symmetric belt system such as that suggested in 1903 by Levau (see Figure 1). However, even the conventional three point system could be greatly improved. Many innovations of the integrated belt system, such as force limiting, automatic size adjustment, reduced slack, and improved fit (all reported by BMW), are already available. Some of these innovations would also improve belt performance in rollover.

A number of exciting technical possibilities exist for improving occupant safety in all crash modes by seat/restraint design. It is suggested that continued experimental research to evaluate improved seat/restraint designs and to assess potential benefits is worthwhile.

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ACCIDENT ANALYSIS

In February 1990, Malliaris (Data Link) produced a report for NHTSA, *"Current Issues of Occupant Protection in Car Rear Impacts".* The report provides an analysis of FARS, NASS, and Polk data up to 1986, relative to rear impact.

The car exposure and casualties for rear impacts, as a percentage of all events for the combined years 1981-1986 are shown in Figure 21. The figure shows that rear impacts constitute approximately 11% of all NASS reported car crashes, but involve only 5% of the fatalities. Among occupants involved in crashes, 12% are in rear crashes, but 23% of those injured are in rear crashes. However, occupants with serious injuries in rear crashes constitute only 7.6% and 3.5% of all serious and fatal injuries, respectively.

It is evident from these figures that rear impacts cause a disproportionate number of minor injuries. However, only a very small fraction of serious and fatal injuries occur in rear impacts.

In spite of the small numbers, it is desirable to further reduce rear impact casualties where practicable. In order to examine the sources of rear impact injuries, the concept of Harm is useful. Malliaris evaluated the distribution of Harm in rear impacts according to injury source. He further separated occupants by restraint use. Figure 22 shows the Harm to restrained occupants; around 20% of the Harm is from unknown sources, illustrating the difficulty in assigning causes of injuries, and noncontact injuries are the cause of another 25% of the Harm. Among contact injuries, the head restraint is the largest source of Harm (17%), closely followed by frontal parts of the car (16%).

The 16% of the Harm caused by frontal elements, such as steering wheels, dashboards, and windshields, may be partially explained by multiple impacts, including those producing frontal deceleration. However, Malliaris also examined the first and second most severe injuries to all occupants involved in single event rear impact crashes. He found that 13% of the most severe injury and 30% of the second most severe injury were from frontal components in the car. The cause of these injuries cannot be determined from the data presented. Potential causes of injuries from frontal components could be:

1. Subsequent non-impact decelerations (a rear impact accelerates a vehicle forward, and a resulting rearward acceleration is inevitable)
2. Energy released from elastic deformation of the seat
3. Flailing of the upper and lower extremities as the occupant moves rearward
4. Vertical acceleration components which may throw the occupant upward into the steering system

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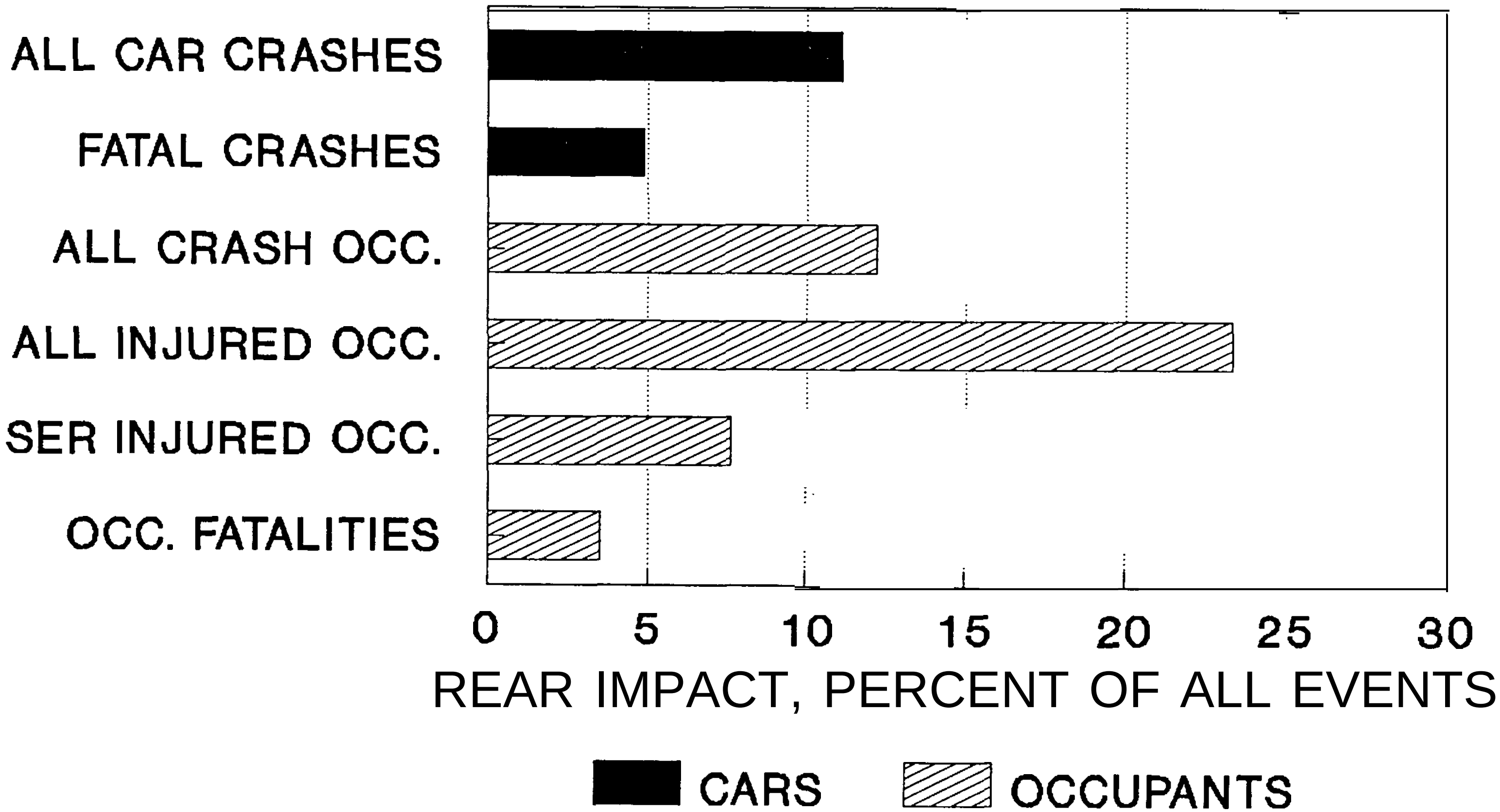
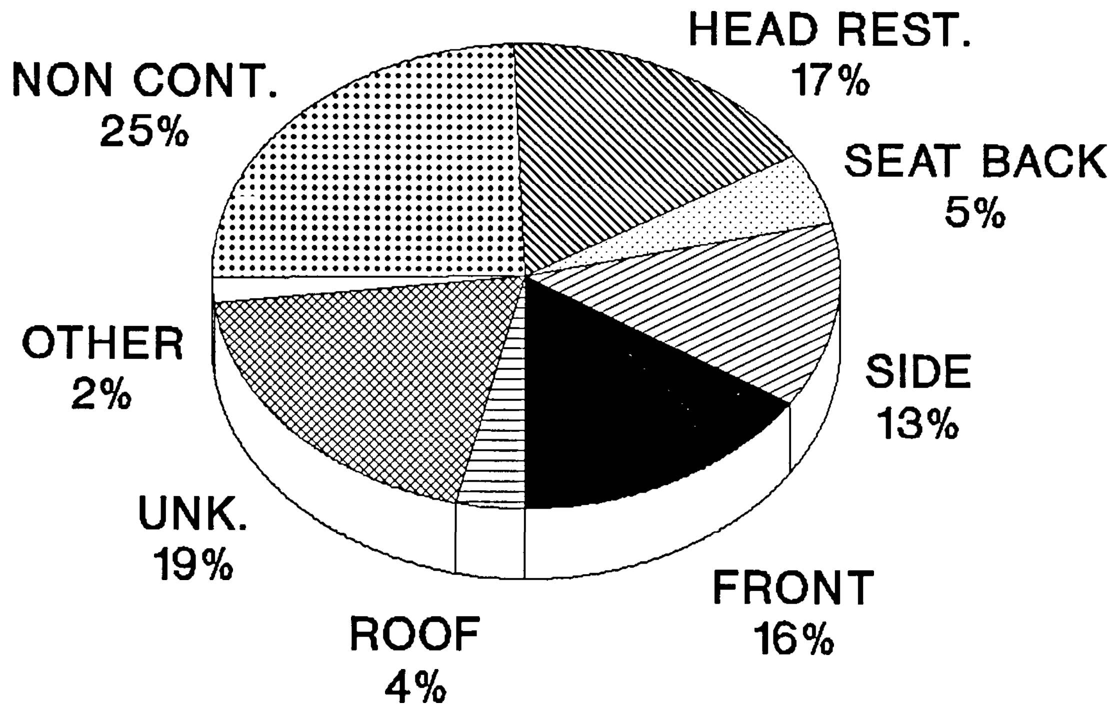
CAR EXPOSURE AND CASUALTIES PERCENTAGES DUE TO REAR IMPACT



NASS;FARS;POLK, 1981-86 (MALLIARIS 1990)

Figure 2 1

HARM DISTRIBUTION BY INJURY SOURCE
RESTRAINED OCCUPANTS; REAR IMPACTS



NASS 1979-86 (MALLIARIS 1990)

Figure 22

In subsequent discussions, all of these factors will be referred to as "rebound". Further research will be required to quantify the extent and presence of the different components which constitute the rebound phenomena, as defined above.

The side interior is the third largest source of contact Harm to restrained occupants in rear crashes. These components constitute 13% of the Harm. Improvement in the restraint capability offered by the seat is a possible countermeasure. Improved interior padding may also contribute to the reduction of this category of injury causation.

The seat back is assigned 5% of the Harm. This appears to be a relatively small amount in view of virtually assured contact with the seat back in a rear collision. However, the contact injuries with the seat back do not necessarily reflect the performance of the seat as an occupant restraint/protection system. Deflection of the seat back could permit the occupant to ramp up the back, exposing him to impact with the roof or a hard structure in the rear of the car. The performance of seats will be discussed later in the section on Investigation of Hard Copy Cases.

Among other sources of injury, the roof was the largest at 3.6%. Rear components were assigned only 0.1% of the Harm. Based on these distributions, impacts with rear components caused negligible Harm in 1979-86 NASS cases for restrained occupants. Contacts with the roof produce a relatively small amount of Harm, when compared with front and side components in the vehicle.

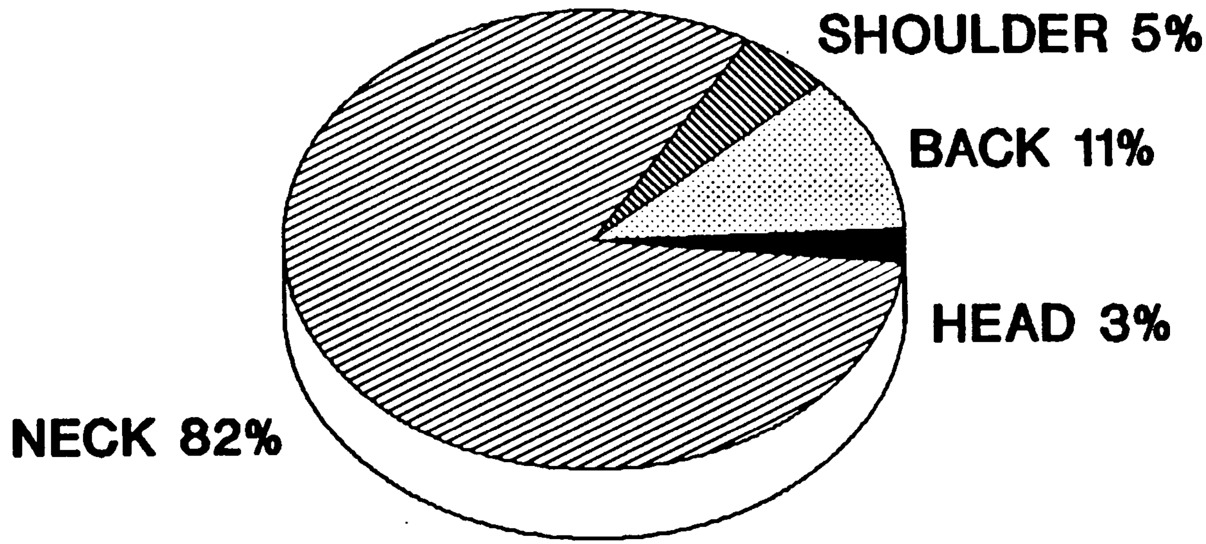
Malliaris did not separate contact Harm by body region. However, he did examine the Harm caused by noncontact injuries. The result is shown in Figure 23. He found that 82% of the noncontact Harm was to the neck. This data suggests that at least 20% of all rear impact Harm to restrained occupants is to the neck. In his 1985 SAE paper, Malliaris found that for all occupants and all crash directions, about 9% of Harm is to the neck. This difference suggests the need for continued improvements in neck injury protection in rear impacts. The presence of head restraints as the largest source of contact Harm and the large fraction of neck noncontnct Harm, suggest that there are opportunities in head restraint design which will produce additional head/neck protection.

INVESTIGATION OF HARD COPY CASES

In order to further evaluate how injuries occur in rear crashes, hard copy cases from the NASS 1988-90 files were reviewed. The purpose of the review was as follows:

030

HARM DISTRIBUTION BY BODY REGION
NONCONTACT INJURIES; REAR IMPACTS



RESTRAINED OCCUPANTS

NASS 1979-86 (MALLIARIS 1990)

Figure 23

Notice 88-20, Notice 3

Please note missing page (P. 24) is the report, "Upgrade Testing –"

- To evaluate the contribution of seat back deformation in producing injuries.
- To evaluate the injuries to front seat occupants produced by the seat's locks, latches, and tracks
- To evaluate the presence of injuries resulting from the occupant ramping up a seat back which is deflected rearward
- To evaluate the presence of injuries resulting from rebound from the seat
- To evaluate the injuries to rear seat occupants produced by the seat's rearward deflection
- To record vehicle make, model, and Δv; to document injury severity, body region, and source for all occupants; to classify injury by direct or indirect; to sketch accident diagram and extent of seat permanent deformation; to record seat failures and the extent of aft intrusion

Three sets of cases were reviewed. Initially, eighteen cases with rear Δv in the 30-39 mph range were reviewed. A second set of cases involved 31 cases selected for AIS 2+ injuries or seat deformation. The third set involved six selected frontal cases with seat deformation.

The case summaries for the eighteen 30-39 mph rear impacts are included in Appendix C, and relevant data for the front seat occupants in these cases is summarized in Table 1. A separate section will deal with rear seat occupants.

Eighteen 30 - 39 mph Δv Cases of Rear Impacts - NASS 1988 - 90

This review encompasses all cases in 1988-90 NASS with rear Δv 30 -39 MPH. Although a small number of cases are present, all the events in the selected severity range are included. However, the unweighted NASS data are only anecdotal evidence. The nationally-weighted data would be needed for any generalizations to national experience. An analysis of the distribution of these cases is presented separately from the other cases investigated. The selection process for the other cases was based on outcome injury severity rather than crash severity, so they are not representative of all crash events in the United States.

Of the eighteen cars involved, three had a front bench seat.

Two cars burned following the crash event - one occupant died in the fire.

Nine of the eighteen cases involved multiple impacts.

Twenty-nine occupants were involved in the eighteen cases, of which nineteen were

031

Table 1

REAR IMPACTS - NASS 1988 - 1990 - DELTA V 30 - 39 MPH

CASE	DELTA V	IMPACT	SEAT POS.	REST. USE	SEAT TYPE	SEAT PERF	YIELD-DEGREES	AIS	INJURY	SOURCE	RAMPING	SEAT DEF OR NONDEF CONTRI TO INJURY	INTRUS. (AFT)	REBOUND
				SEATS WITH NO FAILURE										
90-47-100	31	M	D(23)	YES	2	1	0	1	BACK STRAIN	IMPACT FORCE	NO	NO	22-37	NO
89-46-070	33	M	D(37)	YES	2	1	0	2	CONCUSSION	STEERING WHL	NO	NO	0-40	POSSIBLE
								2	NECK, FRACTURE	NONCONTACT	NO	NO		
90-45-232	39	M	D(30)	YES	2	1	2	2	CONTUS, HEAD	STEERING WHL	NO	NO	33-10	POSSIBLE
				SEATS TEAT DEFORMED										
90-09-067	30	S	D(22)	YES	2	5	15	0	REFUSED TREATMENT		NO	NO	5-44	NO
88-44-113	30	S	D(19)	YES	2	3	30	1	LACER CONTUS	STR WHL FLY GLS	NO	NO	3-42	YES
			P(31)	YES	2	3	30	2	CONTUS, KIDNEY	BROOM STICK	NO	NO		
88-43-002	30	M	D(22)	YES	2	3	45	1	MINOR CONTUS	STR WHL	NO	NO	0-35	POSSIBLE
			P(31)	YES	2	3	30	2	CONTUS, FACE	UNKNOWN	UNK	UNK		UNKNOWN
89-45-121	30	M	D(37)	NO	2	3&4	40	1	LACER CONTUS	STR WHL WNDSHLD	NO	NO	26-5	POSSIBLE
90-47-100	31	M	P(32)	YES	2	5	35	1	MINOR CONTUS	SEAT BK SUNVIS	NO	NO	22-37	POSSIBLE
88-71-042	32	M	S(49) (UNBKL)	YES	2	3&5	45	2	CONTUSION, HD	HEADREST	NO	NO	28-18	NO
88-49-035	32	S	D(27)	YES	1	5	45	2	LACER, ABDOM	SEAT BACK	UNKN	UNKN	0-46	NO
								7	BLUNT TRAUMA	SEAT BELT	UNKN	UNKN		POSSIBLE
								2	CONCUSSION	REAR HEADER	POSS	POSSIBLE		NO
89-78-094	32	S	D(21)	YES	2	5&6	45	1	LACER CONTUS	"A"&"B" PILLAR	NO	NO	20-4	POSSIBLE
			P(35)	YES	2	5&6	30	0				-		
90-73-067	32	M	D(35)	NO	1	6	0	3	FRACTURE, CHEST	STEERING WHL	NO	UNKN	32-12	POSSIBLE
88-47-222	35	S	D(33)	NO	2	5	45	1	LACERATION, FACE	MIRROR	NO	NO	55-1	YES
89-12-091	35	S	D(62)	NO	7	2&5	50	3	CONTUS, CHEST	UNKN	UNKN	UNKN	50-2	UNKN
								2	FRAC-RIB, CLAVIC	LT ARM REST	NO	NO		NO
								2	FRACT, SHOULDER	UNKNOWN	UNKN	UNKN		UNKN
			P(54)	NO	7	2&5	50	1	CONTUS STRAIN	HDRST SEAT BK	NO	NO		NO
88-80-026	35	M	D(27)	YES	2	5	45	1	CONTUS STRAIN	STR WHL BLT IP	NO	NO	35-26	YES
90-02-062	35	S	D(75)	NO	5	5	UNKN	6	BURNS		NO	NO	12-56	UNKN
89-77-160	36	S	D(19)	YES	1	5	70	1	CONTUS CONSUSS	HDREST IP	NO	NO	34-0	YES
90-07-134	37	S	D(20)	NO	6	5	60	1	CONTUSION, CHEST	STERRING WHL	NO	NO	35-11	YES
			P(9)	NO	6	5	60	0				-		-
088-45-262	38	M	D(24)	NO	2	5	30	7	FRACTURE, PELVIS	UNKN	UNKN	UNKN	34-5	UNKN
90-45-232	39	M	P(29)	YES	2	1	20	1	FACE, LACER ABRAS	HDRST FLY GLS	NO	NO	33-10	NO

TABLE 1 - NOTES

IMPACT - S SINGLE M MULTIPLE

SEAT POSITION - D DRIVER(AGE) P RIGHT FRONT(AGE)

INTRUSION FROM AFT - INCHES CRUSH - LEFT CORNER AND RIGHT CORNER

Seat Performance

(0) No seat
(1) No seat performance failure(s)
(2) Seat adjusters failed
(3) Seat back folding locks failed
(4) Seat tracks/anchors failed
(5) Deformed by impact of occupant
(6) Deformed by passenger compartment intrusion (specify):

Seat Type

(00) No seat
(01) Bucket
(02) Bucket with folding back
(03) Bench
(04) Bench with separate back cushions.
(05) Bench with folding back(r)
(06) Split bench with separate back cushions
(07) Split bench with folding back(s)

033

restrained; however, two belt systems released during the crash event - one broke and the other was not properly latched. Out of 25 occupied front seats, 22 yielded.

Eleven of the twenty-five front seat occupants suffered injuries from contacts in the frontal direction. Two of these frontal injury cases involved only rearward crash forces.

The most frequently injured body part was the head and face; the highest severity injuries were inflicted to the head and chest. The most frequently recorded probable source of injury was the steering wheel (9), followed by the seat back (8), headrest (5), and flying glass (4); however, the number of noncontact injuries was equal to the number of injuries caused by the steering wheel.

In this small sample, the rate for AIS 2 and greater injuries for restrained occupants is 26%, while the injury rate for unrestrained occupants is 50%.

The distribution of injuries based on the maximum AIS was as follows:

	Front Occupants	Rear Occupants
AIS 0	3	1
AIS 1	12	3
AIS 2	6	
AIS 3	2	
AIS 4-5	0	
AIS 6	1 (BURN)	
AIS 7	1	

One vehicle was involved in two rear impacts in the same crash event (Case 90-47-100).

Case 90-47-100 also had a driver seat which did not yield and a passenger seat which yielded 35 degrees (as estimated from the available photograph). Both front seat passengers received AIS 1 maximum injuries. Both received back strain injuries from the impact. The passenger received a face contusion from the sun visor, probably in rebound. Rebound appears to occur even in seats which yield.

Case 90-47-100 also had two rear seat occupants. The one behind the the yielding seat received AIS 1 abrasions to the leg and knee from the seat back. The one behind the non-yielding seat received an AIS 1 facial fracture from the back of the front seat.

Ramping of the occupants was difficult to identify. It was not positively observed in any of the cases. It was not relevant to injuries in twenty-one of twenty-nine occupant cases. One AIS 2 head injury (Case 88-49-035) (AIS 2) involved contact with the rear header. Ramping may have contributed to the head injury from the rear header and an associated AIS 2 abdominal laceration from the seat belt. For this case, the seat's permanent deflection was 45 degrees, and the rear intrusion was 46 inches.

Seat deformation performance may have contributed to two of the occupant injuries. In addition to the case cited above, Case 89-78-094 may have seat related AIS 1 level contusions and lacerations. However, rebound impact may also have caused some of the injuries in this case.

Rebound may have contributed to injuries in twelve of the twenty-five cases. In five cases, rebound was definitely involved. In many cases, a frontal impact followed the rear impact, thereby adding to the rebound velocity. The earlier reported finding that the steering wheel is the most frequent cause of injury is consistent with the rebound phenomena observed. Most rebound injuries were minor. However, one AIS 3 chest injury may have been aggravated by rebound (90-73-067). This case also had multiple impacts.

In this limited number of severe rear impact cases, ramping could not be positively identified as contributing to any injuries. It may have contributed to injury in one case. Seat deformation performance may have contributed to one AIS 1 and one AIS 2 injury. However, rebound related injuries were possible in five cases, and probable in seven additional cases. Among these twelve injuries, eight were AIS 1, two were AIS 2, one was AIS 3, and one was an injury of unknown severity.

Thirty-One Selected Injury Producing Rear Impact Cases - NASS 1988

An additional thirty-one cases were selected for hard copy review. These cases had two selection criteria. First, cases with Δv greater than 40 mph were included. This produced two fatal cases. A second group contained restrained occupants with injuries of AIS 2+ or in vehicles with seats deformed by impact of the occupant. The additional case summaries are included in Appendix D.

Table 2 provides a summary of the seat performance for all 49 cases of the rear impact investigated. These 49 cases involve 72 front seat occupants and 26 unoccupied seats.

The following is a summary of the seat performance data of occupied front seats presented in Table 2. The summary contains the number of times each specific seat performance category was assigned to each seat type.

SEAT PERFORMANCE CATEGORY

SEAT TYPE	1*	2	3	4	5	6	7	TOTAL
01*	1				8	1	1	11
02	20	1	12	2	19	2		55
04	1							1
05	1				1			2
06			1		4			5
07	2	2		2				6
ALL	25	3	13	2	34	3	1	81

• See Legend Below

Seat Type

(00) No seat
(01) Bucket
(02) Bucket with folding back
(03) Bench
(04) Bench with separate back cushions
(05) Bench with folding back(s)
(06) Split bench with separate back cushions
(07) Split bench with folding back(s)

Seat Performances

(0) No seat
(1) No seat performance failure(s)
(2) Seat adjusters failed
(3) Seat back folding locks failed
(4) Seat tracks/Anchors failed
(5) Deformed by impact of occupant
(6) Deformed by passenger compartment intrusion
(7) Seat back reclining mechanicsm failed

Nine seats received multiple (two) types of damage. Therefore, there are 81 instances of damage, or non-damage, for the 72 occupied seats. Bucket seats with a folding back lock were the most predominate seats in the cases reviewed, followed by bucket seats. There were 26 unoccupied front seats in the cases reviewed. Four of these seats received damage; three from intrusion, and one coded "seat back folding locks failed".

The predominate mode of damage was seat deformation by the occupant, followed by seat back folding lock failure. Three cases of seat adjuster failure were noted. All were associated with seats deformed by occupant impact. Two of the occupants involved had AIS 1 injuries. In the other case, the principal injury was an AIS 3 chest injury of unknown cause. Improved seat restraint might have mitigated this injury, but the the evidence is uncertain. No AIS 2+ injuries from seat adjuster failure could be positively identified from the rear impact cases examined.

Fourteen cases of folding lock failures were reported. Among these cases, five occupants may have had injuries at the AIS 2 level which were exacerbated by the reported lock failure. The relevant cases are 90-76-019P, 88-50-040D&P, 00-43-002P, and 88-71-042D

036

Table 2

SEAT PERFORMANCE - FRONT SEATS
REAR IMPACTS - 49 CASES

CASE NO.	DELTA V	SEAT POS.	SEAT TYPE	SEAT PERF.	YIELD - DEGREES	AIS
88-45-055	8	D	4	1	0	3
		P(U)	4	1	0	
90-9-158	9	D	1	1	0	2
		P(U)	1	1	0	
90-76-0 19	9	D	2	3	<20	1
		P	2	3	< 10	2
90-71-203	11	D	2	2&5	30	1
		P	2	5	30	1
88-72-040	12	D	2	3&5	10	2
		P(U)	2	1	0	
88-10-092	14	D	2	1	0	3
		P	2	1	0	1
90-80-063	14	D	2	1	0	1
		P	2	1	0	2
90-12-191	14	D	1	5	45	2
		P	1	5	45	1
89-41-008	15	D	2	3.	60	1
		P	2	1	0	2
90-12-129	15	D	2	4&5	45	1
		P(U)	2	1	0	
90-45-24 1	16	D	2	5	20	2
		P(U)	2	1	0	
88- 10-066	16	D	1	5	15	2
		P(U)	1	1	0	
90-12-076	16	D	2	5	25	2
		P	2	5	30	1
90-12-192	16	D	2	5	45	1
		P(U)	2	1	0	

037

CASE NO.	DELTA V	SEAT POS.	SEAT TYPE	SEAT PERF.	YIELD - DEGREES	AIS
90-9-056	17	D	1	(a)	30	2
		P	1	5	30	1
88-81-018	17	D	2	5	35	2
		P	2	5	40	0
88-11-155	17	D	6	5	40	1
		P	6	5	40	1
88-77-079	17	D	5	1	0	2
		P(U)	5	1	0	
89-80-504	18	D	2	3	45	1
		P(U)	2	1	0	
88-47-225	19	D	2	1	0	2
		P(U)	2	1	0	
90-77-151	20	D	7	1	0	2
		P	7	1	0	0
88-45-009	20	D	2	1	0	2
		P(U)	2	1	0	
88-72-159	24	D	2	1	0	3
		P(U)	2	1	0	
88-46-032	24	D	6	3	0	2
		P(U)	6	1	0	
88-9-110	25	D	1	5	40	2
		P	1	5	40	1
39-11-141	25	D	2	1	0	2
		P(U)	2	1	0	
33-50-040	25	D	2	3	60	2
		P	2	3	60	2
83-30-033	28	D	2	1	0	3
		P	2	1	0	0
88-41-073	28	D	2	5	<10	2
		P	2	1	0	3
90-9-067	30	D	2	5	15	7
		P(U)	2	1	0	

038

CASE	DELTA V	SEAT POS.	SEAT TYPE	SEAT PERF.	YIELD - DEGREES	AIS
88-44-113	30	D	2	3	30	1
		P	2	1	30	2
83-43-002	30	D	2	3	45	1
		P	2	3	30	2
89-45-121	30	D	2	3&4	40	1
		P(U)	2	3	40	
90-47-100	31	D	2	1	0	1
		P	2	5	35	1
88-71-042	32	D	2	3&5	45	2
		P(U)	2	1	0	
88-49-035	32	D	1	5	45	2
		Pi U)	1	6	0	
89-78-094	32	D	2	5&6	45	1
		P	2	5&6	30	0
90-73-067	32	D	1	6	0	3
		P(U)	1	1	0	-
89-46-070	33	D	2	1	0	2
		P(U	2	6	0	
88-47-222	35	D	2	5	45	1
		P(U)	2	1	0	-
89-12-091	35	D	7	2&5	50	3
		P	7	2&5	50	1
88-80-026	35	D	2	5	45	1
		P(U)	2	6	0	
90-2-062	35	D	5	5	(1)	6
		P(U)	5	1	(1)	-
89-77-160	36	D	1	5	70	1
		P(U)	1	1	0	
90-7-134	37	D	6	5	60	1
		P	6	5	60	0
88-45-262	38	D	2	5	30	7(2)
		P(U)	2	1	0	

039

CASE NO.	DELTA V	SEAT POS.	SEAT TYPE	SEAT PERF.	YIELD - DEGREES	AIS
90-45-232	35	D	2	1	0	2
		P	2	1	28	1
88-45-103	42	D	2	1	38	1
		P	2	1	0	2(3)
88-10-160	48	D	2	1	(1)	5(3)
		P(U)	2	1	0	

D - Driver

P - Right Front Passenger

(U) - Unoccupied

(1) - Burned - Unable to determine yield.

(2) - Fractured pelvis

(3) - Fatality.

(a? - Seat back reclining locks failed.

Seat Type

(00) No seat
(01) Bucket
(02) Bucket with folding back
(03) Bench
(04) Bench with separate back cushions
(05) Bench with folding back(r)
(06) Split bench with separate back cushions
(07) Split bench with folding back(s)

Seat Performance

(0) No seat
(1) No seat performance failure(s)
(2) Seat adjusters failed
(3) Seat back folding locks failed
(4) Seat tracks/anchors failed
(5) Deformed by impact of occupant
(6) Deformed by passenger compartment intrusion (specify):

040

(D-Driver, P-Right Front Passenger). In four of five cases, the source of the AIS 2 injury is unknown. Consequently, the evidence of seat lock failure contribution to injury is obscure.

Two cases of seat anchorage failures were reported. The maximum injury for the occupants in both of these cases was AIS 1. Seat anchorage failures were not associated with any serious rear impact injuries.

The performance of seats with regard to ramping, deformation, and rebound is summarized in Tables 3 and 4. In these Tables, only injuries of AIS 2 and greater were considered in the analysis. For completeness, data from the eighteen cases (Δv 30-39) were also included, provided the injury to the occupant was AIS 2 or greater. Of the 72 front seat occupants in 49 cases, only 35 occupants met the criteria for inclusion in the analysis presented in Tables 3 and 4.

The analysis separates the data into two groups: Table 3 - no seat yielding; and Table 4 - cases with permanent seat back yielding.

In cases with no permanent seat back yielding, all but one of the 17 occupants was restrained. No injuries were identified which resulted from ramping or seat related deformation. However, frontal injuries were present in eight of the cases. This suggests the presence of "rebound" phenomena, as previously defined. In most cases it is the result of a subsequent frontal collision.

In cases with permanent deformation, 16 of the 18 occupants were restrained. Seat deformation may have contributed to 3 of the injuries, and ramping may have contributed to one. However, rebound is also frequently present. Seven of the 16 occupants had injuries from frontal sources. Four of the cases were single event rear impacts.

For both sets of data, 15 of 35 occupants had injuries from frontal components. These results suggest that "rebound" exists in present seat designs, whether they deform or not. Further, rebound injuries are more frequent than those associated with seat deformation. This result is consistent with the earlier finding by Malliaris, which showed that 16% of Harm in rear crashes is from frontal components of the vehicle. This compares with 0.1% of the Harm from rear components of the vehicle.

Analysis of Rear Seat Occupants

There were eight cases in which vehicles contained rear seat occupants. A summary of these cases is contained in Appendix E. Some minor AIS 1 injuries could be attributed to

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Table 3

CASES IN WHICH THERE WAS NO SEAT FAILURES AND TEE OCCUPANT INJURY MEASURE WAS AIS 2 OR GREATER

CASES	DELTA	IMPACT	BEST. USE	SEAT POS	AIS	INJURY	SOURCE	INTRUSION FROM AFT	RAMPING
88-45-055	8	S	Y	D	3	CONCUSSION	UNKNOWN	7-l	UNKNOWN
90-09-158	9	M	Y	D	2	CONCUSSION	SUNVISOR(R?)	0-l	NO
88-10-092	14	M	Y	D	3	KNEE, LACERATION	INST PANEL(R?)	6-5	NO
90-80-063	14	M	Y	P	2	CONCUSSION	UNKNOW	2-3	UNKNOWN
89-41-008	15	M	Y	P	2	RIB FRACTURE	SEAT BELT(R?)	l-19	NO
88-77-079	17	S	Y	D	2	CONCUSSION	UNKNOW	6-4	UNKNOWN
88-47-225	19	S	Y	D	2	HEAD LACERATION	"B" PILLAR	18-3	NO
90-77-151 (BENCH)	20	M	Y	D	2	CONCUSSION	HEADREST	2-33	NO
88-45-009	20	M	Y	D	2	CONCUSSION	STR WHL(R?)	12-18	NO
88-72-159	24	M	Y	D	2	CONCUSSION	UNKNOWN	25-22	UNKNOWN
89-11-141	25	M	Y	D	2	CONCUSSION	STR WHL(R?)	26-44	NO
88-80-033	28	M	Y	D	3	BURNS	BATTERY ACID	24-00	NO
88-41-073	28	M	Y	D	3	CHEST FRCTURE	SEAT BELT(R?)	4-43	NO
89-46-070	33	M	Y	D	2	CONCUSSION	STR WHL(R?)	0-40	NO
					2	NECK, FRACTURE	NONCONTACT		
90-45-232	39	M	Y	D	2	CONTUS, HEAD	STR WHL(R?)	33-10	NO
88-45-103	42	S	Y	P	2	NEAK FRAC FATAL	NONCONTACT	25-41	NO
88-10-160	48	S	N	D	5	CONCUSSION	UNKNOWN	41-41	UNKNOWN
						FATAL BURNS			

IMPACT - S SINGLE - M MULTIPLE (R?) - POSSIBLE REBOUND INTRUSION FROM CRUSH - LEFT C CORNER
RESTRAINT USE - Y YES - N NO SEAT POS - D DRIVER - R RIGHT FRONT

TABLE 3 - NOTES

IMPACT — S SINGLE M MULTIPLE
SEAT POSITION — D DRIVER (AGE) P RIGHT FRONT (AGE)
INTRUSION FORM AFT — INCHES CRUSH — LEFT CORNER AND RIGHT CORNER

Seat Performance

(0) No seat
(1) No seat performance failure(s)
(2) Seat adjusters failed
(3) Seat back folding locks failed
(4) Seat tracks/anchors failed
(5) Deformed by impact of occupant
(6) Deformed by passenger compartment intrusion (specify):

Seat Type

(00) No seat
(01) Bucket
(02) Bucket with folding back
(03) Bench
(04) Bench with separate back cushions
(05) Bench with folding back(s)
(06) Split bench with separate back cushions
(07) Split bench with folding back(s)

Table 4

CASES IN MICE THE SEAT YIELDED AND THE OCCUPANT INJURY MEASURE WAS AIS 2 OR GREATER

CASES	DELTA V	IMPACT USE	BEST. POS.	SEAT	AIS	INJURY	SOURCE FROM AFT	INTRUSSION ANGLE	YIELD	RAMPING OR NONDEFOY	SEAT DEFORM CONTRIBUTES TO INJURY
90-76-019	9	S	Y	P	2	SHOULD DISLOC	UNKNOWN	0-4	10-20	UNKNOWN	UNKNOWN
88-72-040	12	S	Y	D	2	CONCUSSION	WINDSHLD(R)	2-2	10	NO	NO
			(LOOSELY)								
90-12-191	14	S	Y	D	2	LEG CONTUSION	INSTR PNL(R)	12-0	45	UNKNOWN	POSSIBLE
90-45-241	16	M	Y	D	2	FRACT CLAVICLE	SEAT BLT(R?)	0-14		NO	NO
88-10-066	16	S	Y	D	2	CONCUSSION	SEAT BACK	0-12	20	NO	UNKNOWN
90-12-076	16	S	Y	D	2	CONCUS HEAD	"B" PILLAR	18-0	25	NO	UNKNOWN
						CONTUS SHOUL					
90-09-056	17	M	Y	D	2	CHEST FRAC	STR WHL(R?)	19-0	30	NO	NO
88-81-018	17	S	Y	D	2	KNEE,LG CONTU	INSTR PNL(R)	17-0	35	UNKNOWN	POSSIBLE
88-90-110	25	M	Y	D	2	CONCUSSION	STR WHL(R?)	27-8	40	NO	NO
88-50-040	25	S	Y	D	2	CONCUSSION	UNKNOWN	19-22-15	60	UNKNOWN	UNKNOWN
				P	2	CONSUSSION	UNKNOWN		60	UNKNOWN	UNKNOWN
					2	LACER,FACE	UNKNOWN			UNKNOWN	UNKNOWN
88-41-073	28	S	Y	D	2	CONCUSSION	UNKNOWN	4-43	<10	UNKNOWN	UNKNOWN
88-43-002	30	S	Y	P	2	LACER FACE	UNKNOWN	0-35	45	UNKNOWN	UNKNOWN
88-44-113	30	S	Y	P	2	CONTUS,KIDNEY	BROOM STICK	3-42	30	NO	NO
88-71-042	32	M	Y	D	2	CONTUS, HD	HEADREST	28-28	45	NO	NO
			(UNBUCKLED)								
89-49-035	32	S	Y	D	2	LACER,ABDMN	SEAT BACK	0-46	45	UNKNOWN	UNKNOWN
					7	BLUNT TRAMA	SEAT BLT(R?)		UNKNOWN		UNKNOWN
					2	CONCUSSION	REAR HEADER			POSSIBLE	POSSIBLE
89-12-091	35	S	Y	D	3	CONTUS, CHEST	UNKNOWN	50-2	50	UNKNONX	UNKNOWN
90-92-062	35	S	N	D	6	BURNS		12-56	UNKN	NO	NO
88-45-262	38	S	N	D	7	PELVIS, FRACT	UNKNOWN	34-5	30	UNKNOWN	UNKNOWN

IMPACT - S SINGLE - M MULTIPLE   (R?) POSSIBLE REBOUND   (R) - REBOUND   RESTRAINT USE - Y YES N NO

SEAT POS - D DRIVER P PASSENGER   INTRUSION FROM AFT - INCHES   CRUSH - LT. CORNER AND RT. CORNER the front seat deformation. However, it is not possible from the data to assess the degree to which front seat deformation contributes to the injuries of rear seat occupants.

Six Selected Frontal Impacts

These six cases involve three seats which are reported to have track/anchorage failures, two which deformed under occupant loading and one which moved forward under impact. The cases are summarized in Appendix F.

For the seats which were deformed by occupant impact, no contribution of the seat to the injury was evident. However, for the seat that moved forward during a frontal impact and the three track/anchorage failures, seat contribution to the injury severity is possible. In all of these cases, occupants experienced injuries higher than expected for the crash severity. The higher injuries were consistent with those expected from undesirable seat loading of the occupant.

OTHER STANDARDS FOR SEAT STRENGTH

The history of FMVSS developments for seats is summarized by Warner (91) and will not be repeated here. It is evident that other countries generally followed the U.S. standards. A comparison of the strength requirements for various countries is summarized in Table 5. All require 20 g empty seat strength.

The 20 g peak acceleration is typical for passenger car structures in frontal barrier crashes at speeds of 30 mph. However, vans and small front wheel drive cars frequently experience higher occupant compartment G's than that of most passenger cars. In addition, recently designed anti-submarining seats, such as those shown in Figure 15, result in significant occupant loading being transferred to the seat. Finally, the incorporation of belt anchorages on the seat structure requires much higher loadings than currently addressed by the seating standard.

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Table 5

Summary Comparison of U. S . and
Other Country's Seating Strength Requirements

Country	Test Force on Seating System C.G. of Seat	Test Moment on Seating Reference Pt. (Per Designated Occ.)	Test Force on Seat Back Lock C.G.-Seat Back
U.S.A.	20g	3,300 in-lb	20g
Canada	20g	3,300 in-lb	20g
ECE Reg. #17 Rev. 3	20g	4, 690 in-lb (53 daNm)	20g
Japan	20g	3, 300 in-lb (Approx.) (33 Kg-m) 3,291 "#	20g
Sweden	2 0g	3, 300 in-lb (Approx.) (5 8 Kg - m)	20g
Brazil	20g	3 .300 in-lb	20g
Australia	20g	3,300 in-lb	20g

* Sweden and Australia use ECE Regulation #17 as alternative.

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FILM ANALYSIS

In order to further investigate the performance of seats in rear impacts, preliminary film analyses of rear impact tests conducted under FMVSS 301 were undertaken. Five test films were reviewed. In four of the tests, the seat was permanently deformed. In one test, of a Honda Accord, no permanent seat deformation was noted. This test was subjected to film analysis to determine the rebound velocity of the occupant. It was found that the seat underwent extensive elastic deformation. The dummy head nearly disappeared below the rear window sill during the impact. The elastic energy of the seat was then transferred to the dummy as rebound velocity. Film analysis indicates a rebound velocity of about 11 mph.

Additional film analysis and case studies are required to draw definite conclusions on the rebound performance of existing seats. However, this limited analysis and the "rebound" frequency found in the accident data suggests the need for further investigations.

CONCLUSIONS

This preliminary analysis suggests that improvements in seat performance is a more complex matter than simply increasing the strength of the seat back. Legitimate concerns exist over the potential increase in neck injuries and rebound injuries which might accompany strengthened seats.

Harm analysis by Malliaris provides insights of injury frequency and severity in rear impacts. His analysis shows that noncontact neck injuries constitute more than 20% of the Harm to restrained occupants. The head restraint is the largest source of contact Harm (17%). The role of head restraints in noncontact neck injuries and contact head injuries needs to be studied in conjunction with any seating system modifications.

Foret-Bruno (91) found a significant increase in head restraint effectiveness as seat back strength in Renault cars was increased to meet the EEC standard. He suggested that the lower-strength, prestandard seats deformed at a force level below that which induces noncontact neck injury. He concludes that strengthened seats are likely to increase the demand on head restraints to mitigate the neck injury risks.

Our data analysis did not permit the quantification of neck injury risks for deformed versus nondeformed seats. In the accident cases we analyzed, we found three noncontact neck fractures in seats which did not deform. No noncontact neck fractures were observed in seats which deformed.

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"Rebound" type injuries occur frequently in crashes which involve rear impacts. Malliaris found that 16% of the Harm in rear impact NASS cases was from frontal contacts. In many of the cases, the rear impact is followed by a frontal impact, either in a line of stopped traffic, or by being accelerated into a fixed object. In these cases, and in cases where no subsequent impact occurs, injuries from impact with frontal components of the vehicle are frequently observed. For the data set of AIS 2+ injuries in selected rear impacts, injuries from frontal components were believed to be present in 15 of 35 occupants. It is not possible to determine how many of these injuries were related to the elastic response of the seat, or from other phenomena. However, some seat induced rebound phenomena can be observed in FMVSS 301 rear impact tests. It is evident that the rebound phenomena needs to be researched in conjunction with future seat improvements.

RECOMMENDATIONS FOR DATA COLLECTION REFINEMENTS

As a result of reviewing hard copy cases, we believe that some additional data collection elements should be considered for future crash investigations.

A recorded measurement of seat back angle and direction of damage would be most helpful. The accident investigator could accomplish this much more accurately than is possible from photographs in the accident file. In addition, photographs specifically taken to document the distorted back angle of the seat would be helpful. In some cases, existing photographs show seats which are displaced rearward, but with the seat performance coded "no failure". In some cases, the seat position may have been changed post accident to aid occupant extraction. A notation to explain differences between coded data and photographs would be useful.

A more explicit coding of the nature of back damage should be considered. The performance of the reclining mechanism should be included. The coding of yielding versus rupture (complete breakage) would provide additional insights.

The position of the head restraints is not currently coded. Head restraint position is a desirable variable in assessing head restraint performance.

The coding of points of occupant contact for the "Seat, Back Support" could be enhanced. At present, the coding does not distinguish between the rear sear occupant contacts with the back of the front seat or the back of his own seat. A code could be added to clarify this ambiguity.

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References

[Adomeit, 1979] Adomeit, D., Seat Design - A Significant Factor for Safety Belt Effectiveness, Institute for Automotive Engineering, Technical University Berlin, SAE 791004, 1979.

[Armstrong, 1968] Armstrong, R.W., Waters, H.P., Stapp, J.P., "Human Muscular Restraint During Sled Deceleration." Proceedings of Twelfth Stapp Crash Car Conference. New York: SAE, 1968.

[Babbs, 1963] Babbs, F.W., Hilton, B.C., "The Packaging of Car Occupants--A British Approach to Seat Design", Proceedings, 7th Stapp Car Crash Conference, p. 456, 1963.

[Berton, 1968] Berton, R.J.: "Whiplash: Tests of the Influential Variables." SAE 680080, Automotive Engineering Congress, Detroit, MI. January 8-12, 1968.

[Burland, 1974] Burland, D., "Occupant Protection in Rear Impact", 5th Experimental Safety Vehicle Conference, June 4-7, 1974.

[Carr, 1988] Carr, W.W.; J.E. Posey, W.C. Tincher: "Frictional Characteristics of Apparel Fabrics," *Textile Research Journal,* 0040-5175/88/58003, p.129, March, 1988.

[Curren, 1968] Curren, B.C., Cox of Warford Ltd., personal communication, Oct. 19, 1968.

[Cornell Laboratory, 1967] Cornell Aeronautical Laboratory, Inc, Integrated Seat and Occupant Restraint Performance, Technical Report, U.S. Dept. of Transportation, Vol. I, September 1967.

[Data Link, 1990] "Current Issues of Occupant Protection in Car Rear Impacts," prepared for Office of Crashworthiness, Rulemaking, NHTSA. Data Link, Inc., Washington, D.C. Feb., 1990. Docket 89-20-NO1-021.

[DeHaven, 1951] DeHaven H., and Hasbrook, A.H. Hasbrook, "Shoulder Harness: It's Use and Effectiveness". Aviation Crash Injury Research, Cornell University. AF Tech Report 6461. Wright-Patterson AFB, Dayton, February 1951.

[Dinapoli, 1977] Dinapoli, N., Fitzpatrick, M., Strother, C., Struble, D., Tanner, R., "Research Safety Vehicle Phase II, Vol. II, Comprehensive Technical Results", Contract #DOT-HS-5-01215, November 1977.

[Fairchild-Hiller, 1967] Fairchild-Hiller, "The Safety Sedan." Final report, Phase II, Vol. I. Design Development of the Safety Sedan, FHR 3526-1, November 1967.

[Foret-Bruno, 1990] Foret-Bruno, J.Y.; C. Tarriere, J.Y. LeCoz, C. Got; F. Guillon: "Risk of

Cervical Lesions in Real-World and Simulated Collisions." 34th AAAM Conference Proceedings, Scottsdale, Arizona, p. 373, October, 1990.

[Foret-Bruno, 1991] Foret-Bruno, J.Y., Dauvilliers, F., Tarriere, C., Influence of the Seat and Head Rest Stiffness on the Risk of Cervical Injuries in Rear Impact, 13th ESV Conference, Paris, France, November 4-7, 1991.

[General Motors, 1989] General Motors, "Seatback Performance in Rear Impacts," USG 2751 Attachment. Robert A. Rogers, General Motors Director, Automotive Safety Engineering, Dec. 4, 1989. Docket 89-20-NO1-009.

[Haberl, 1989] Haberl, J., Ritzl, F., Eichinger, S., The Effect of Fully Seat-Integrated Front Seat Belt Systems on Vehicle Occupants in Frontal Crashes, ESV Conference Goteborg, May 1989.

[Hilyard, 1973] Hilyard, Joseph F.; Melvin, John W.; McElhaney, James H.: "Deployable Head Restraints." Highway Safety Research Institute, University of Michigan. DOT-HS-800-802. Jan. 31, 1973.

[Hilton, 1966] Hilton, B.C., "Design of Low Cost Seating for Effective Packaging of Vehicle Occupants", Proceedings, 10th Stapp Car Crash Conference, (SAE 660797), November 8-9, 1966.

[Hilton, 1967] Hilton, B.C., "Design of Low Cost Seating for Effective Packaging of Vehicle Occupants." Proceedings of Eleventh Stapp Car Crash Conference. New York: SAE, 1967.

[Highway Safety Research Institute, 1967] Highway Safety Research Institute, Integrated Seat and Occupant Restraint Performance, University of Michigan, Ann Arbor, October 1967.

[Hu, 1977] Hu, A., Bean, S., and Zimmerman, R., "Response of Belted Dummy and Cadaver to Rear Impact", SAE 770929, Proceedings, 21st Stapp Car Crash Conference, 1977.

[Hu, 1978] Hu, A.S., Bean, S.P., Zimmerman, R.M., "Response of Belted Dummy and Cadaver to Rear Impact", DOT HS-803 028, NHTSA, Final Report, January 1978.

[Hu, 1980] Hu, A.S., Bean, S.P., "Response of Belted Dummy and Cadaver to Rear Impact", DOT HS-805 792, NHTSA, Final Report, December 1980.

[James, 1991] James, Michael B.; Strother, C., Warner, C., Decker, R.L., and Perl, T.R.: "Occupant Protection in Rear-end Collisions: I. Safety Priorities and Seat Belt Effectiveness." Proceedings of the 35th Stapp Car Crash Conference, San Diego, CA. November 1991.

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APPENDIX A

Summary from 1967 SAE

Report by Severy

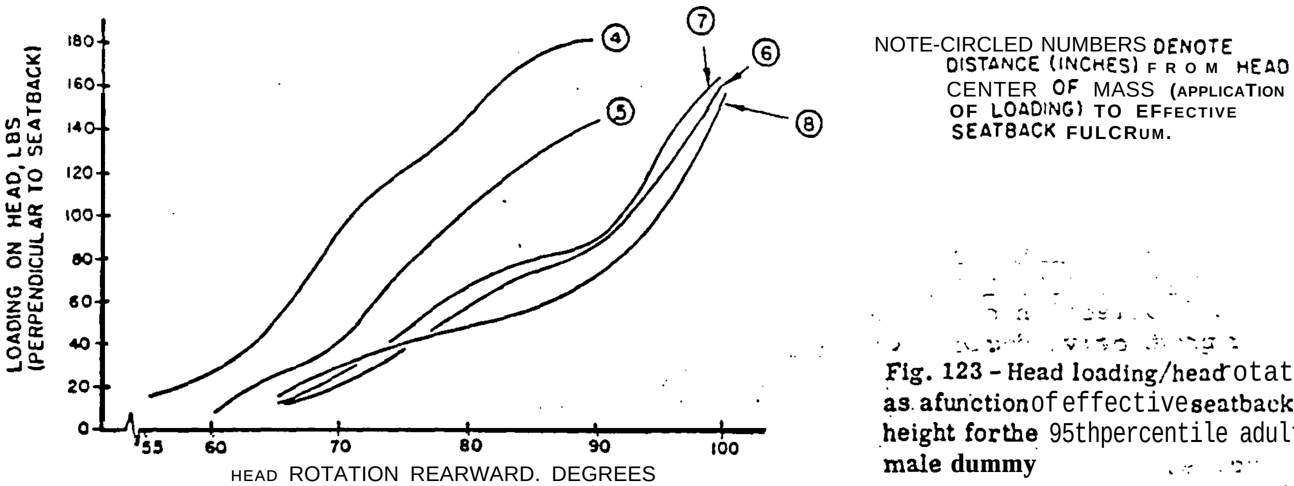

Fig. 123 - Head loading/head rotation' as a function of effective seatback height for the 95th percentile adult male dummy

This graph illustrates what might be intuitiveiy concluded, namely 'that high inertial forces may act through the center of mass of the unrestrained head and neck combination during a whiplash exposure and that the "whiplash" potential injury, per se, may not be clearly evident because the seatback height was sufficient to apply a "rabbit-chop" fulcrum at some level of the neck that reluces limits of voluntary neck excursion, and at the same time increases injury producing shear and bending stresses.

CONCLUSIONS

In the conclusions that follow, the authors wish to point out that these statements are based on specific observations, the majority of which should not be over-interpreted to form generalized conclusions. However, because of the wide variety of conditions evaluated, certain conclusions are broad, not because of a specific observation, but because of a multiplicity of observations that are correlative and that reinforce a specific conclusion, thereby providing a foundation for some degree of generalization.

A. CONCLUSIONS - METHODOLOGICAL - The foundation of scientific inquiry is its methodology, procedures devised for evolving information not commonly available and not readily verifiable. The reader's confidence in data subsequently developed depends on the methdology, the comprehensiveness of the studies and the reputation of the investigators.

1. The twelve rear-end collision experiments reported by this paper are representative of the majority of collision exposures, particularly as related to severity. Passenger vehicles travel in a stream of traffic columnated by lane guide-lines: it is not surprising, therefore that e'rrors in speed control result in rear-end collisions that are either single or multiple and that most frequently occur with no appreciable offset or differences in vehicle heading at impact. The speeds evaluated, 10 thrbugh 55 mph represent the majority of injury producing exposures.

2. These collision experiments provide conditions sufficiently realistic and comprehensive to adequately evaluate the relative merits of various passenger vehicle rear-end collsion protective devices and to identify related injury producing factors. Severe whiplash injuries were inferred from these rear-end collisions: these results indicate that a practical level of collision force was obtained for evaluating relative performances of different seatback and head restraint designs.

3. These experiments were planned with a primary objective of developing reference material needed by engineers designing seatback and head restraints for passenger vehicles. For this reason, many variations in design and manufacturing techniques were not included in the interests of holding the experiments to a manageable number.

4. The use of both 50th percentile and 95th percentile adult male anthropometric dummies provided a practical evaluation of the effect of the average and the nearly largest passenger sizes on the various collision protective de-

vices evaluated. Prior studies (4) established that smaller sized subjects, including children are well protected riding in seats adequately protecting adults.

5. On a selective basis, variations in seat types, seat strengths, seatback heights and related protective devices were evaluated under realistic conditions. Selection of a practical variety of protective devices was made to provide objective data useful in making performance judgements concerning units not specifically evaluated in these studies.

6. Comprehensive instrumentation was used in these studies to provide detailed specifics required for safety performance evaluation of the rear-ended passenger vehicle. The use of properly articulated anthropometric dummies, 55 transducers and 29 photographic units represented the most comprehensively instrumented passenger vehicle collision study conducted to date. The extensive photographic coverage of each human simulation during the entire collision event provided new insight into injury causation.

7. The utilization of instrumented full size vehicles providing realistic collision conditions and instrumented trauma-indicating anthropometric dummies simulating passenger collision, their induced movements, and the use of high speed motion picture color photography overlapping all collision movements represents a most practical and reliable method for determining passenger vehicle rear-end collision performance. An evaluation was made of the several procedures in use by research groups in the U.S. and abroad. concerned with accidental trauma; the consensus of opinions concurred with this methodological approach. While it is true that fatal injury trauma varies greatly from individual to individual and this range is not understood with any great degree of precision, nevertheless, the procedures used in this study provided an exacting basis for determining the relative performances of safety devices. It is more important to learn which passenger environment provides the most practical and effective improvement to passenger protection than to delve into refinements concerned with the specific traumatic conditions required for Permanent injury or death. Progress with the safe transportation of humans will always be a relative matter - there will never be a practical arrangement for transportation that guarantees no injuries.

a. The presence of double or higher order variables was controlled through appropriate methodology to ensure reliability of findings. In this study, the techniques of redundancy in instrumentation.and absolute constancy of factors involved, except for the single variable under study, were used as control devices. For example, the seating side-by-side of two identical dummies with identical restraints in identical seats and identical postures except for specific head offset variation provided a means of establishing the precise role minor variations in head-offset may play in motorist protection.

B. CONCLUSIONS - COLLISION PERFORMANCE - The collapse resistance of a rear-ended vehicle as a function of impact speed, the susceptibility of the vehicle to passenger compartment encroachment, the comparative resultant accelerations, the influence of vehicle components on injury causation, the preservation of passenger compartment integrity while undergoing moderate levels of impact acceleration are examples of vehicle collision responses characterizing collision performance. In the ordinary use of a vehicle, these deficiencies do not usually manifest themselves and frequently escape observation by accident investigators owing to the transient nature of these deficiencies or the investigator's lack of familiarity with levels of collision' performance. Adequate collision performance provides the passenger with a protective shield from the crashing structures of the primary impact: adequate passenger compartment safety protects the passenger from the injury producing forces of the secondary impact the one in which the passenger may be hurled against the compartment interior or ejected. This section relates to the former and the section to follow, to the latter.

1. The rather linearly varying passenger compartment peak accelerations sustained for speeds of rear-end impact between 10 and 55 mph attest to the excellent force modulating properties of

the rather collapsible 1967 Ford rear-end structure. The collision performances of 1967 Fords undergoing rear-end collision produces a rather-linear increase in peak acceleration of the passenger compartment as a function of the impacting car speed. The mutual or collective collapse for the rear-end collision car increases exponentially for speeds from zero through 30 mph and linearly at speeds from 30 to 55 mph. The rear end of the struck car becomes sufficiently "bottomed out" at 30 that its stiffness amplifies substantially to provide the linear deformation for the 30 to 55 mph range, notwithstanding the exponential changes in kinetic energy as a function of impact speed. The permanent collpase changes with impact speed for the striking car varies linearly between 10 and 30 mph and at an increased rate: it varies linearly between 30 and 55 mph.

2. The cause of fuel tank leakage for impact speeds between 20 and 30 mph was attributed to disassociation of filler spout from the fuel tank and collapse of the car bodv axle housinq step with which both the rear axle and the fuel tank are carried. Extension of the length of the filler spout by the manufacturer during the production year largely corrected the filler spout problem and the collapsing of body floor section to crush into the tank could be averted by stiffening that section.

C. CONCLUSIONS - PASSENGER COMPARTMENT - In the passenger compartment angular protrusions as well as rigid material with small radii surfaces are prevalent and represent injury producing areas that should be eliminated. Passenger compartment design criteria for motorists' protection should conform to referenced standards. Injury producing objects in the passenger compartment should be recessed or eliminated rather than attempt to pad the object superficially or ineffectively.

1. The rear window and header was contacted for some exposure conditions, even by the 50th percentile dummy and for most exwsures by the 95th percentile dummy. Window and header impacts may serve to reduce head to torso axis misalignment but are accompanied by highly objectionable impact accelerations. Because of the unpredictability of the head restraining value derived from window and header impacts, both as to its probability of occurrence 'and as to its practicality as a "restraining" device, rear window and header restraining action is not regarded as asatisfactory condition. Some form of rear seat seatback restraint for the head is recommended, whether simply an extension in seatback height or as an extension of padding onto the window ledge behind the passenger. When the header is missed, head accelerations are several times less but the probability of injury producing whiplash is virtually assured unless a head restraint has been provided.

2. Force amplifying structures should be relocated, recessed or eliminated. Angular sections in the passenger compartment as well as small radii surface of rigid material represent injury sites that should be eliminated. For example, the rear window and its header were frequent impact sites for the rear-ended tall rear seat passenger. Those passengers not sustaining this abuse, because they were shorter, whiplashed over the rigid low seatback, their necks receiving injury producing forces from striking the angular junction of the seatback support and rear window shelf.

3. Rear seat passenqers that strike their heads aqainst the rear window or header may prevent whiolash action, as a result of sustaining a direct head blow several orders of magnitude higher than whiplash acceleration. In addition to this factor, the wedge-like impact developed by the 30 degree slope of the rear window (from horizontal) may cause injury producing vertebral compressive forces.

4. Thin padding, less than one-half inch thick applied to seatback top-edge surfaces over rigid frame structures serves little practical value. Design criteria for passenger protection should conform with the standards referenced at the beginning of this section. Fixed objects of this nature should either be recessed rather than attempting to compensate errors of design with superficial and ineffective padding.

5. The production bench seat (24 degree seatback angle) intersects the horizontal rear window ledge with an acute angle of 66 degrees. Except for

the ineffective readily compressible padding, the fulcrum-like wedge is positioned to give the average motorist a dangerous "rabbit-chop" to the back of the neck or head. The section of the passenger vehicle trunk directly behind this wedge is the least accessible and could well be reduced in volume by contouring the junction of the sheet metal frame supporting the seatback and the rear window ledge. Readily compressible seatback padding can be increased in depth to restore the desired seatback geometry and the transverse structural properties afforded by this ledge would, if anything, be improved by the contour.

D. CONCLUSIONS - SEATING UNITS - Seat designs ranging from production bucket and bench seats to combinations of high seatback, rigid and non-rigid construction, tack-on head restraints and specially constructed safety seats were evaluated under a wide range of realistic collision severities.

1. A list of passenger protective devices would generally show belt restraints at the top, with seats, a close second, The compartmentalization of properly designed high-back seats provides a very valuable constraint for most horizontal directions of impact. The performance of safety belts and harnesses in this study followed the lines clearly established in prior experiments (2), (3), (8). Properly designed restraining devices direct collision forces to the strong parts of the body in a manner least likely to produce injuries.

2. Without question, the most important vehicle seating position is the front seat: this is because the majority of the average passenger car mileage is accomplished with no rear seat passengers and, additionally, when rear seat passengers are included, the front seat serves as a protective barrier for them.

3. Properly designed passenger vehicle seats provide an inner protective shield around their precious cargo while also compartmentizing the passengers to reduce the possibilities of their impacting one another during all but the most devastating of collisions. In general, seats in passenger vehicles, if structured for collision safety, represent the most important single life-saving device available to the motorist, once a collision becomes unavoidable. The properly structured high-back seat applies the restraint needed by the motorist for protection from the injury producing forces of rear-end collisions just as the shoulder and lap safety belts protect the motorist against the injury producing forces of a head-on collision.

4. A bench seat, modified from a 21-inch to a 25-inch seatback was found to provide sood protection for the average-sized (50th percentile) rear seat motorist undergoing the moderately severe 30 mph rear-end collision: his head did not strike the rear window or header and rebound was negligible.

5. Seatbacks found to be of adequate height for one level of collision exposure will not necessarily provide adequate head restraint at higher levels owing to a combination of increased seatback deflection and tendency for head and torso displacement up the inclined plane of the seatback. The higher forces associated with more severe impacts, positions the head inertial force vector operating through the center of mass of the head aimed rearward over the top of the backrest serving to pull the head rearward over the head restraint to a posture more likely to result in whiplash. In addition to the variable increases in speed of impact, as a contribution to whiplash severity; the height of a seatback is an obviously singularly important variable.

6. Seatback height for all passenger vehicles should be at least 28 inches. These experiments indicate that an adequately structured 28-inch rigid seatback (seatback strength over 16,000 but not over 33,000 in.-lbs) will provide satisfactory protection against the injury producing forces of most rear-end collisions: head offset can cause variations in seatback deflections and head peak acceleration but both factors can be safely accommodated in the majority of exposures. High-back seats (28 inches or more) greatly contribute to the compartmentalization of passengers thereby reducing the chances of injuries sustained by passengers being hurled against one another, regardless of their size.

7. Seatback yield represents a condition that may reduce the amount of head adverse posturing relative to torso (whiplash) during a rear-end collision. However, it is not practical to consider seatback yield as a protective design feature owing to the wide range of performances needed for a controlled-yield. The many variables having to do with the severity of rear-end collision forces makes this approach impractical.

8 . Plastic deformation of high seatbacks (front seats) reduce passenger's rebound toward the windshield in rear-end collisions but greatly increase chances of injury for any rear seat passengers thrown against them. During moderate speed rear-end collision experiments, high-backed seats offered adequate support for the head and torso and when the seatback yielded rearward approximately 20 degrees, rebound was diminished. This rebound hazard would be intensified if a front-end impact occurred, following the rear-end collision. A disadvantage however, of the seatback being forced into a semi-reclined position is that the passenger to the rear is more likely to strike it on rebound. Additionally, the more reclined angle facilitates sliding by the motorist up the seatback, thereby extending his head further beyond the end of the head restraint.

9. Elastic rebound of seatbacks increases the chances of passengers sustainins multiple impact injuries. Increasing seatback rigidity through designs that allow for only minor controlled yield with only nominal elastic action reduces rebound of motorists following peak accelerative forces of a rear-end collision: this consistent observation is explained on the basis that the elastic energy that can be stored by the upholstery padding and springs as the seat crushes forward into the backs of the motorists is negligible when contrasted with the metal seatback frame, anchorages and floor pan elastic energy for designs allowing significant elastic rebound.

10. Rear seatback yield was insignificant for speeds of impact through 30 mph and very slight (to 1½ inches) for speeds of impact through 55 mph, attesting to the rigid nature of rear seatback structures.

11. Even at 30 mph a 28-inch seatback (95th adult) should have a deformable or energy absorbing top edge in order to conform to neck arch during the rear-end loading.

12. Front seat passenger protection against the injury producing forces of rear-end collisions using the current design technique of seatback failure is unsatisfactory. Not only is the passenger subjected to the random chance of critical injuries sustained from striking the rear surfaces of the car interior or the rear seat passengers, the driver is so adversely positioned that he loses all opportunity of regaining control of his vehicle in time to avert potentially more serious secondary collisions. This explains the reason a weak seatback is not recognized as an acceptable solution for motorist protection from rear-end collisions.

13. Rigid seatbacks assure more effective support of the occupant during rear-end collisions, providing the seatback support is high enough to also resist rearward movement of the head. Conversely, a seat that yields appreciably rearward (e.g. more than one foot rearward displacement, as measured at the head restraint elevation) places the motorist in a semi-reclined posture that may serve to attenuate some of the injury producing forces but at the same time adversely displaces the motorist to higher elevations relative to the seatback, thereby reducing the measure of support that may be derived.

14. The more rigid the seatback, the less the tendency of head and torso displacement up the plane of the seatback during a rear-end collision; to the extent that a forward tilt design is incorporated in a seatback at its upper limits, this adverse torso shirt is less likely to occur since this design feature straightens the inclined plane of the seatback where it's unneeded but encountered during torso shift.

15. Increasing seatback rigidity reduces rebound of motorists following peak accelerative forces of a rear-end collision: this consistent observation is explained on the basis that the elastic energy that can be stored by the upholstery padding and springs as the seat crushes forward into the backs of the motorists is negligible when con-

trasted with the metal seatback frame. elastic energy for designs allowing significant elastic yield.

16. Seat assemblies and anchorages should not fail from collision accelerations under 20 G from rear-end impacts. The fact that most seat anchorages held during the UCLA Series V rear-end collision experiments is attributed to the following factors: most of the seats were special units and required individualized techniques to anchor them.' The UCLA engineers made certain these anchorages would sustain the contemplated impacts so that evaluations of protective restraints, etc., would not be compromised by hardware failure.

17. As a restraining material, the relative ineffectiveness of upholstery, having conventional stress/strain characteristics, indicates why its thickness should be kept to a minimum, consistent with comfort, in order to provide the motorist with the greater measure of head and back restraint possible with the extended seatback metal structure.

18. The use of rigid metal trim across the top of bucket seatbacks exposes the rear-ended front seat motorists as well as the front-ended rear seat motorist to head impacts with injuries amplified by these non-yielding sharp surfaces. Padding such trim in the position of most probable impact is ineffective unless the padding is dense.

19. Seatbacks and arm rests should be designed using well padded, broad surfaced metal frames designed to provide the required strength and to attenuate head impact forces. The seat requires a strong frame to prevent seat. inertial forces and passenger inertial (impact) forces from excessively deflecting it and breaking it free from its mounts. This strength must be designed into the seat so that small surface areas, and rigid structures are not encountered during "bottoming-out" type head impacts, occasioned by rebound from rear-enders, or direct impact by rear seat passengers thrown into front seatbacks during head-on impacts.

20. In the high-back seat, a contour forward feature for upper third of the seatback provides restraint against torso sliding up the plane of the seat. Relatively small vertical downward forces are required to neutralize the torso movement'up the plane of the seatback; a properly designed shoulder harness, integral with the seatback, would accomplish this objective.

21. A seatback having differential strength with least bending moment at top would reduce the dangerous fulcrum-like action of head restraints that do not reach high enough to support the head mass. This matter deserves further research and the-preferred solution, based on current information, is to provide vehicles with-head restraints high 'enough to obviate the fulcrum-like action problem.

E. CONCLUSIONS - HEAD RESTRAINTS - Head restraints are devices that restrain the rearward movement of the head relative to the seatback so as to maintain the head and torso axes in a natural relationship during a rear-end collision.

1. Rear-end collisions are one of the most common types of accidents: even low speed impacts can be crippling. Head restraints, designed to function as a part of the seatback, represent a satisfactory, and the best known, solution to this problem. Head restraints should not be optional equipment because that status should be reserved for items not involving motorist safety.

2. Head restraints are as important to the motorist involved in rear-end collisions as the safety belt is to the motorist involved in a front-end impact: the safety belt provides "brakes" for motorists in front-end impacts and the properly designed seatback with head restraint provides "brakes" for the rear-ended motorist's head'and torso. The

3. The head restraint for front seat units should be designed as an extenion of the seatback and preferably not as an attachment or an adjustable unit. Additionally, because of the somewhat critical nature of head restraint position relative to the head and its response to seatback inertial and head impact forces, the concept of attaching the head restraint to the roof structure, independent of the seatback, is regarded as objectionable on the basis that it compromises motorist protection and can be a source of injury during upset and other types of collision exposure.

4. The closer the head restraint

to the motorist's head, the better his protection. Head offsets from the head restraint to six inches do not greatly increase a motorist's exposure to injury.

5. Static tests for head restraint performance yield generally exceed the corresponding dynamic yield value owing to force augmentation attributable to seatback inertia not present with static tests. This condition depicts the capacity of the restraint to resist adverse head movement but does not include the requirement for resisting the restraint's own inertial force.

6. Properly devised laboratory static tests of seatbacks with head restraints represents a satisfactory procedure for evaluatins head restraint performance, where correlative data is available from dynamic full-scale studies. This conclusion assumes experimental sophistication in terms of including sufficient realism in the laboratory procedure to avoid such serious possible omissions as floor pan yield, seat anchorage bolt bending and yield, and the possible interaction of vehicle fixed interior surfaces with seatback yield and occupant displacement.

7. The head restraint should not be weaker than the seatback. If the seatback yields or fails, the head restraint should maintain the same relationship.

Failure of the head restraint may expose injury producing structures to the occupant flailed against it. Seatback failure, while an undesirable condition, does not generally represent serious injury exposure unless accompanied by failure of the head restraint with respect to the seatback.

8. For the 10 mph impact, a 95th percentile adult male dummy on a rear (bench) seat receives some measure of head restraint from the sloping (30 decree horizontal) rear window. The quality or protective aspects of this wedge-like impact type of restraint is suspect, not only because it cannot be counted on for variations in posture and dummy heights, but also because the restraining force is accompanied by a vertically downward vector that may at times reach sufficient magnitude to cause injury to the spinal processes. Pear seat positions should be provided with head clearance sufficient to prevent significant contact with vehicle interior by a 95th percentile adult male undergoing a rear-end collision by an equivalent striking car traveling between 10 and 40 mph faster than the rear-ended car at impact.

9. Head restraints should be an integral part of the vehicle, preferably requiring no adjustment, if they are to provide the most consistent and effective protection against rear-end collision injuries, The width of the seatback near the upper (head restraint) can be reduced to accommodate increased visibility, without significantly reducing the overall protection afforded by the head restraint.

10. Seatbacks not designed to accommodate the added stress of properly desisned and constructed retrofitted head restraints will in general, nevertheless, provide greatly improved passenger Protection when so equipped. This modification, when competently managed, provides the motorist with a means for maintaining a normal head-to-torso axes alignment; the probability of gross seatback deflection or failure is viewed as an undesirable condition but one which would occur anyway and a condition for which structural revision would probably be too expensive to be practical.

11. Seatbacks extended sufficiently to provide effective head restraint need not interfere with driver rear-view direct vision or driver see-through-car-ahead vision, providing the head restraint Position of the seatback does not exceed the recommended width of 15 inches. This dimension for driver and right front seat passenger allows adequte see through vision, even for small cars, and a motorist has no problem seeing around it when looking to the rear.

12. Head restraints whether an integral extension of the seatback or a tack-on unit should be 15 inches wide but not less than 10 inches wide. Head restraints less than 10 inches wide, while perhaps adequate for square-on rear-end collisions, pre-supposes perfect postural alignment at the time of impact: owing to the natural lateral shifts in posture of the motorist and the possible occurrence of oblique rear-end collisions, a bias toward the 15-inch dimension will provide protection

for a wider range of rear-end collision exposures. Head restraints wider than 15 inches represent a problem for drivers attempting to see through cars ahead when traveling at highway speeds under congested conditions.

13. As a practical matter of comfort, the head restraint should be no closer than one inch from the back of the head when the motorist is in a natural seated position.

F. CONCLUSIONS - OCCUPANT PROTECTION - During the whiplash phase of a rear-end collision, the extent to which the head axis remains aligned with the torso axis is a common measure of whiplash severity: other factors such as the head peak acceleration attained, the effective elevation of the seatback (potential for neck "rabbit-chop") and the presense of dangerous interior surfaces that the head may strike, represent other mechanisms by which motorists are injured from rear-end collisions.

1. "Whiplash" as used by the 'authors connotates the motorist's involuntarily assumed, injury producing, torso and head-to-torso postures occasioned by automobile collisions and other forms of trauma.

2. In addition to the extent of 'whiplash" injury exposure, as characterized by the angle the head axis assumed rearward of the torso axis, the location of back and neck force applications and their magnitude are also important indicators of potential injury exposure. For this reason, those exposures that do not manifest a critical approach to the voluntary limits of head excursion relative to the torso axis and yet are accompanied by significant whiplash or head impact with the vehicle interior should also be regarded as unacceptable solutions to the protection of motorists from rear-end collision injuries.

3. A 95th percentile dummv in a 16,100 in.-lb. 28-inch high front seat will sustain during a 30 mph rear-ender nearly half the head and chest acceleration of a 95th percentile dummy in the rear seat, extended also to 28 inches. This observation is attributed in part to the closer proximity of the rear seat to impact and also the more rigid seatback construction of rear seats in Passenger vehicles.

4. With respect to head offset for the 28-inch seatback, the 95th percentile dummy and the 30 mph rear-end collision exposure, the followins conclusions can be made:

(a) Head impact remained relatively constant for 0, 3 and 6 inch offsets (e.g., 11, 11, 10 G) but increased substantially for the 12-inch offset (e.g., 18 G).

(b) Chest and knee accelerations as well as seat belt force did not vary with changes in head offset.

(c) Maximum deflection and permanent rearward deflection of seatbacks remained constant for 0 and 3-inch offsets but was significantly reduced for 6 and It-inch head offsets. This seeming anomaly is explained by considering the dynamic responses of both head and its head support; they perform as a single mass for 0 and 3-inch offsets and their inertial forces became asynchronous for the larger 6 and 12-inch offsets. Seatback asynchrony with occupant head and torso inertial forces reduces the extent of seatback deflection.

5. Increases in head offset increases tendency for whiplash: normal posture variations of twelve inches were found to cause only slight modifications in whiplash as contrasted with the more dominant variables of seatback height and strength.

6. A twelve-inch head of'fset for a rear seat passenger in a standard bench seat will more than double chest acceleration as contrasted with a zero-inch head offset during a rear-end collision; this is attributed to the exceptionally rigid construction of seatbacks for the rear seat position.

7. A twelve-inch head offset as compared with a 3-inch offset degrades the protection of a head-restraint bv an amount approximately equivalent to diminishing the head restraint height by three inches. Design criteria associated with protection devices for the motorist represents a combination of compromises. The problem of unusual head offset at the time of impact is compatible with the problem of excessive seatback yield common to higher speed rear-end collisions; both conditions are obviated by higher seatbacks but higher seatbacks impose additional restrictions to driver's and motorist's visibility. This identifies the compromised con-

dition governing the authors' recommendations for a 28-inch seatback.

8. In addition to "head-offset," it is useful to consider the extent to which readily compressible upholstery further separates the motorist's head from his head restraint. To this end, one can refer to the "Effective Head-Offset," the combination of head-offset and the compressible depth of the up-holstery before bottoming-out occurs.

9. Seatback and head restraint upholstery, depending on its thickness, account for a aignificant amount of the "effective head-offset." Upholstery characteristically offers low force resistance to deflection. To the extent that upholstery is unnecessarily deep for the comfort purpose intended, its depth serves to unnecessarily compromise the motorist by allowing higher differential velocities between the seatback and his head and torso.

10. Owinq to variations in the effective elevation.of the head restraint, the extent of whiplash injury exposure is not simply a matter of the difference in head axis to torso axis' angles because lesser angles are required to physiologically exceed spinal voluntary limits of articulation as a function of the effective elevation of the top of the back restraint. These variations have to do with motorists' seated height variations and with the yield performance characteristics of the backrest undergoing collision. Where head restraint occurs below the skull level, some cervical vertebra may be restrained against flexion, but those vertebra above the restrained segment are free to flex beyond voluntary limits and owing to the reduction in articulation units, the extent of flexion for injury is correspondinqiy reduced.

11. The seat belt does not contribute significantly to passenger protection from rear-end collision exposures:

(a) The floor anchored lap belt, and to a lesser extent the seat anchored lap belt pivot about their attachments as the motorist is accelerated. This action increases seat belt slack allowing the motorist to slide up the plane fo the seatback, thereby resulting in a reduced level of back support as the whiplash forces reach their maximum values.

(b) The low-back seats (less than 25-inch seatbacks) become even more hazardous during a rear-end collision if a seat belt is being worn because forward movement of hips is restricted thereby increasing the bending moment sustained by the spinal column. The seatback acts as a fulcrum with the lap belt lower limb inertial forces acting at at the base of the spine and the unrestrained head and shoulder inertial forces acting at the upper end of the spine.

(c) Seatbacks found to be of adequate height for one level of collision exposure will not necessarily provide adequate head restraint at higher levels owing to a combination of increased seatback deflection and tendency for head and torso displacement up the inclined plane of the seatback. The higher forces associated with more severe impacts, positions the head inertial force vector operating through the center of mass of the head aimed rearward over the top of the backrest serving to pull the head rearward over the head restraint to a posture more likely to result in whiplash.

(d) The more rigid the seatback, the less the tendency of head and torso displacement up the plane of the seatback during a rear-end collision: to the extent that a forward tilt design is incorporated in a seatback at its upper limits, this adverse torso shift is less likely to occur since this design feature straightens the inclined plane of the seatback where it's unneeded but encountered during torso shift.

G. CONCLUSIONS - GENERAL - These experiments have verified the importance of keeping the head and torso axes aligned by a properly designed seatback; the experiments have also established that every whiplash-protective device evaluated demonstrates some measure of degradation of performance as the relative speed increases between the rear-end collision vehicles. The degradation of seatback performance for protection of the motorist from whiplash as a function of speed increased seatback yield caused by increased body and seatback inertial forces attending high speed impacts that position the torso in a more reclined posture thereby facilitating its movement up the plane of the seat. Some tendency of this nature occurs even without seatback yield because of the natural 20 degree slope of seatbacks.

1. For the moderately severe collision exposures reported in this paper, (to 55 mph), it was established that a well designed safety seat would protect most passengers from sustaining significant rear-end collision injuries. It is apparent that far safer seats can be provided on the basis of performance guidelines established by this paper. The higher initial investment that provides greatly improved safety and comfort is money well spent.

An adequately designed, properly structured and anchored high-back contoured seat (28" or higher, well padded backrest) provided with well padded armrests, harness or a lap belt that is built into the seat-unit with retractable, inertial-lock mechanism represents the essential features of a safety seat that provides sufficient protection for a motorist to sustain, with probably no more than minor injuries, rear-end collisions through 55 mph. The crash performance of seats designed as safety seats represents a decided improvement over conventional seats. This was established in a prior series of experiments designed to evaluate the Liberty Mutual safe-seat configuration, Reference 3. As demonstrated by the Cox contour safety seat with head support and built-in cross-chest lap-belt restraint, the average motorist from child to adult size can ride out a severe rear-end collision (e.g. up to the 55 mph exposure) without significant injury.

2. Seatback strength should include allowance for passengers thrown forward against the backrest. Even though passenger vehicles are provided with lap belts, not all passengers will be sensible or knowledgeable enough to use them. Additionally, lap-belted taller persons can flail their heads and chest against the seatbacks ahead of them during front-end impacts, if not on rebound from rear-end collisions..

3. Front seat motorists are adequately protected from rear-end collision injuries for striking car speeds through 30 mph if they have an adequately structured 28-inch seatback capable of sustaining without failure a 16,100 in.-lbs. inertial force; head offset may cause variations in seatback deflections and head peak accelerations but both factors can be safely accommodated in the majority of exposures.

4. The importance of considering the head restraint protection for the 95th percentile dummy is not so much a special concern for the welfare of the minority-population of "kins-sized" males as it is a recognition of the fact that seatback heights, satisfactory for the average adult at low-speed rear-end collisions, must be significantly higher for equivalent protection at higher collision speeds. Seatback height-s and strengths providing satisfactory protection for the 95th percentile adult male for 30 mph rear-enders will provide satisfactory protection for the average height motorist for speeds through 30 and substantially above 30 mph.

5. These experiments were structured to be comprehensive but there were observations made during the experiments that suggest further avenues of profitable inquiry:

(a) The top surface of a seatback may provide improved head restraining properties during a rear-end collision if it extends rearward as a ten to twelve inch padded shelf. This design may serve to reduce the minimum elevation required for reasonable protection from whiplash.

(b) The upholstery material and texture used opposite the shoulders for a high-back seat may significantly influence the tendency for torso shift up the plane of the seatback.

(c) The rear window and adjacent metal structures provide a wedge-like surface for the head to strike. As the head contacts this inclined plane (30 degrees), assuming no other hazardous contact such as with a projection, the peak acceleration is produced by the wedge-like application of accelerative forces to the head and this may cause excessive compressive forces of the vertebral column. The magnitude of these forces was not instrumented but they may be physiologically significant and both the 95th and 50th percentile male dummies sustained relatively high head impacts with the rear window.

6. Properly designed high back seats provide an inner protective

shield around the passengers while also compartmentizing them to reduce the possibilities of their interacting with each other during all but the most devastating of collisions. In general, seats when structured for collision safety, represent the most important single life-saving device available to the motorist.

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REFERENCES

1. Severy, D. M., J. H. Mathewson, and C. 0. Bechtol, "Controlled Automobile Rear-End Collisions - An Investigation of Related Engineering and Medical Phenomena, Series I," Canadian Service Medical Journal, Vol. XI, Nov. 1955, pp. 727-759 (ITTE Reprint No. 40).

2. Severy, D. M., and J. H. Mathewson, "Automobile Barrier and Rear-End Collision Performance," SAE Preprint 62C, a paper presented at the Society of Automotive Engineers Summer Meeting, Atlantic City, New Jersey, June 8-14, 1958.

3. Severy, D.M., H. M. Brink and J. D. Baird, "Collision Performance LM Safety Car," SAE Preprint No. 670458, May 15-19, 1967, 79 pp. Presented at the Society of Automotive Engineers, Chicago, Illinois, May, 1967.

4. Severy, D. M., H. M. Brink and J. D. Baird, "School Bus Passenger Protection,? SAE Preprint No. 670040, January, 1967, 165 pp. Presented at the Society of Automotive Engineering Congress, Detroit, Michigan, January 1967.

5. Gay, J. R. and K. H. Abbott, "Common Whiplash Injuries of the Neck," J. Am. Med. Assoc. 152:1698, 1953.

6. Ommaya, Ayub K., Arthur E. Hirsch and John L. Martinez, "The Role of 'Whiplash' in Cerebral Concussion," Proceedings of the Tenth Stapp Car Crash Conference, Paper No. 660804; published by the Society of Automotive Engineers, Inc., November 1966.

7. Wickstrom, J., J. L. Martinez, D. Johnston and N. C. Tappen, "Acceleration-Deceleration Injuries of the Cervical Spine in Animals," Proceedings of the Sevehth Stapp car crash Conference, D. M. Severy, Ed., Charles C. Thomas, Publisher, 1965; presented at Los Angeles Nov. 1963.

8. Severy, D. M., J. H. Mathewson and A. W. Siegel, "Automobile Head-On Collisions, Series II," SAE Transactions, Vol. 67, 1959, pp. 238-262.

9. Severy, D. M. and H. M. Brink, "Safety Glass Breakage by Motorists During Collisions," Proceedings of the Tenth Stapp Car Crash Conference, published by the Nolte Center for Continuing Education of the General Extension Division, University of Minnesota, Minneapolis, M. K. Cragun, Editor, 1966; pp. 205-23.6.

10. Severy, D. M., "Human Simulation for Automotive Research" SAE SP-266, January 1965, presented to the Society of Automotive Engineers, Automotive Congress and Exposition, Detroit, Michigan, January 13-17, 1964.

APPENDIX B

Seat & Rear Impact

Test Data

APPENDIX A - SEVERY TESTS WITH CALIBRATED SEATS

		TEST CONDITIONS				TEST RESULTS			
XPERIMENT NO.	VEHICLE DELTA V (MPH)	DUMMY TYPE (AND RESTRAINT)	HEAD OFFSET (INCHES)	CALIBRATED SEAT BACK TORQUE (IN-LBFS) (FORCE AT 14")	SEAT BACK HEIGHT (INCHES)	SEAT BACK RESIDUAL ANGULAR DEFLECTION (DEGREES)	SEAT BACK DYNAMIC ANGULAR DEFLECTION (DEGREES)	REMARKS	
x93	16.5	95M (L)	3	9,100 (650 lbf)	22	19	27	Seat back rotated rearward to strike rear dummy knees. Dummy in rigid rear seat experiences head G's twice that of this dummy (24G v. 12G).	
x94	11.0	95M (L)	3	9,100 (650 lbf)	22	8	14	Dummy in rigid rear seat experiences head acceleration about three times this dummy (23G v. 8G).	
x93	16.5	95M (L)	0	16,100 (1150 lbf)	22	7	16	Dummy in rigid rear seat experiences head acceleration about twice this dummy (23G v. 22G). Seat back may have hit rear dummies knees.	
x94	11.0	95M (L)	0	16,100 (1150 lbf)	22	3	10	Dummy in rigid rear seat experiences head acceleration significantly higher than this dummy (50G v. 14G). Head rotated more than i x93 (see above line).	
x95	16.5	95M (L)	6	16,100 (1150 lbf)	22	3	10	Dummy in rigid rear seat experiences head acceleration about twice that of this dummy (19G v. 10G).	
x95	16.5	95M (L)	12	16,100 (1150 lbf)	22	4	10	Dummy head acceleration higher due to greater offset.	
x96	16.5	95M (L)	3	16,100 (1150 lbf)	25	7	16	Dummy in rigid rear seat experiences head acceleration about twice that of this dummy (24G v. 11G).	
x96	16.5	95M (L)	3	16,100 (1150 lbf)	28	8	17	Dummy in rigid rear seat experiences head acceleration about twice that of this dummy (21G v. 11G).	
x97	5.5	95M (L)	0	16,100 (1150 lbf)	28	0	7	Dummy in rigid rear seat experiences head acceleration about 2.5 times that of this dummy (24G v. 10G).	
x98	22.0	95M (L)	3	16,100 (1150 lbf)	28	21	33	Dummy ramped up seat back to get head over head rest. Seat back contacted rear dummy knees. Dummy in rigid rear seat experiences head accelerations about 2.5 times that of this dummy (75G v. 33G).	
x100	16.5	95M (L)	6	16,100 (1150 lbf)	25	7	20	Dummy leaned forward about 10 degrees. Sever whiplash motion.	
x100	16.5	95M (L)	6	16,100 (1150 lbf)	28	11	23	Dummy leaned forward about 10 degrees. Seat back almost bottomed out. Head rest protecte against whiplash motion.	
x101	16.5	95M (L)	12	16,100 (1150 lbf)	25	14	22	Ramped up seat with severe whiplash motion. No apparent contact of seat back with rear dummy knees.	
x101	16.5	95M (L)	12	16,100 (1150 lbf)	28	18	29	Severe whiplash motion. Strong rebound with chin bottoming on chest.	
x102	16.5	50M (L)	0	16,100 (1150 lbf)	25	0	7	Whiplash motion of head. Dummy rebounded int steering wheel.	
x99	16.5	95M (L)	0	33,000 (2357 lbf)	25	0	7	Whiplash motion was significantly larger compared to x96.	
x99	16.5	95M (L)	0	33,000 (2357 lbf)	28	0	7	Whiplash motion was significantly larger compared to x96.	
x102	16.5	50M (L)	0	33,000 (2357 lbf)	25	0	10	Whiplash motion similar to driver (see above). Head bottomed out on chin during rebound.	
x103	30.25	50M (L)	0	33,000 (2357 lbf)	25	6	18	Seat back bottomed out against rear seat dummy knees. Floor pan yielded. Driver ramped up seat back with severe whiplash motion. Rebounded into steering wheel.	
x103	30.25	95M (L)	3	33,000 (2357 lbf)	18	15	25	Seat yielded, bottomed out against rear dummy knees. Dummy headed for severe whiplash motion when contact with rear dummy chest occurred. Cox seat in left rear yielded back and bottomed out on rear package tray.	
x104	30.25	50M (L)	0	33,000 (2357 lbf)	28	8	21	Beam (4" channel) placed under front seat anchor. Head over top of seat back with severe whiplash motion, rebounded into steering wheel.	
x104	30.25	95M (L)	3	33,000 (2357 lbf)	28	10	18	Beam in place (see above). Seat bottomed out against rear dummy knees. Severe whiplash motion with severe rebound motion.	
x106	30.25	50M (L)	0	97,000 (6929 lbf)	29	0	0	Cox Seat with back against beam welded between b-pillars. Ramping and rebound controlled by integral belt system.	
x106	30.25	50M (L)	0	97,000 (6929 lbf)	28	0	0	Calibrated seat with beam against seat back. Dummy ramps 4" up back despite lap belt.	

APPENDIX B - REAR IMPACT CRASH TESTS INVOLVING PRODUCTION SEATS 1967-1978

REFERENCE DATA			IMPACT CONDITIONS						RESULTS	
DATE OF REPORT	TITLE OF PUBLICATION (SOURCE DATA)	AUTHOR(S) (CORP. AUTHOR)	TEST NO.	STRIKING VEHICLE OR OBJECT	CASE VEHICLE	CASE VEHICLE DELTA V (MPH)	DUMMY USED (WT)	RESTRAINT	RESIDUAL CHANGE IN SEAT BACK ANG (DEGREES)	REMARKS
10/67	Preliminary Findings of Head Support Designs (11th STAPP)	Severy, Brink & Baird (ITTE, UCLA)	x93 x94	'67 Ford "	'67 Ford "	16.5mph 11.0mph	95M(D) 95M(D)	Lap Lap	19 8	Actually seats were lab. seats. Tests shown with S/B cal. @ 650# (14") - i.e. per prod. seats (9100 in.lbfs)
1/68	Backrest and Head Restraint Design for Rear Impact Protection (SAE 680079)	Severy Brink & Baird (ITTE, UCLA)	x97 x98	'67 Ford "	'67 Ford "	5.5mph 19.9mph	95M(D) 95M(D)	Lap Lap	1.5 12	Production seats used. Except for add. of 6" head restraint.
11/73	Six Rear Moving Barrier Automobile Crash Tests (GEI Rept. A 4650.01) (IIHS Cont. No. 6561)	H.E. Holt (General Environment Corporation)	1	Rigid M.B	'73 Ambassador	15.1mph	50M(2)	??	Fully Reclined	Split bench seat.
			2	"	'73 Ply. Fury	14.7mph	50M(2)	??	"	Fixed bench seat back.
			3	"	'73 Toyota Corona	19.0mph	50M(2)	??	"	Fixed bench seat back.
			4	"	'73 Chev. Vega	19.1mph	50M	??	"	Bucket seats.
			5	"	'73 Ford Pinto	19.1mph (calc.)	50M	??	"	Bucket seats.
			6	"	'73 Opel 1900	19.0mph (calc.)	50M	??	"	Bucket seats.
9/74	Automotive Rear-end Collision Tests (NHTSA Report DOT-HS-801-163)	Scheuerman & Young (NAFEC)	428	Rigid M.B	'68 Ply.	8.5mph	95M(D) 50M(C) 95M(P)	None	3.5	Bench seat.
			433	"	'68 Ply.	9.8mph	Same as above	None	18(L)	Bench seat adjusted. Head rests dropped 2".
			437	"	'68 Ply.	14.3mph	"	None	14.5(L)	Bench seat. Left side hit knees of rear dummy.
			438	"	'68 Ply.	16.2mph	"	None	15.5(R)	Bench seat. No rear seat dummies. Front seat moved back unit r. seat contact.
			441	"	'69 VW 1	22.7mph	95M(D) 95M(P)	None None	27 16	50M behind passenger seat Driver seat slipped back to r. seat. Passenger seat hit r. pass. (50M) knees.
			461	"	'71 Pinto	19.8mph	95M(D) 95M(P)	None None	25 --	50M behind p. seat. Driver seat slipped back to hit r. seat. Passenger seat rear legs collapsed.
			462	"	'70 Buick Electra	12.4mph	95M(D) 50M(C) 95M(P)	None None None	19.5(L) 34.5(R)	Bench seat. Front seat impacted r. dummies knees.
			463	"	'69 Ply. Sta.wagon	9.6mph	Same above	None	28(L) --(R)	Bench seat. Left side hit r. dummies knees. Seat broke loose from floor.
			468	"	'70 LTD	14.7mph	Same as above	None	34(L) Note(R)	Bench seat. Dr. dummy head hit r. dummy chest. Pass. dummy head hit rear seat back. Seat broke loose from floor.
			469	"	'68 Ply.	9.3mph	59M(D) 50M(P)	None	7	No rear dummies.
			470	"	'68 Ply.	17.2mph	50M(P)	None	29(L) 34(R)	No rear dummies.
10/73	Six Moderate Speed Front-into Rear Automobile Crash Tests (GEI Report A.-4348.10) (IIHS Contract #6539)	H.E. Holt (GEI)	1	'73 AMC Gremlin	'73 Toy Corona	23.5mph	*M(D) F(P)	L&S "	Yes** Yes**	*Department store manikins filled to proper weight for size with rubber mat. Male(M) - 153#, Female (F) - 112#
			2	'73 Datsun 610	'73 Ford Pinto	21.9mph	*M(D) F(P)	" "	Yes** Yes**	
			3	'73 Ford Gal 500	'73 AMC Ambassador	21.3mph	*M(D) F(P)	" "	Yes** Yes**	**No angles measured Rear seat manikins helped prevent further seat back rotation.
			4	'73 VW Type I	'73 Ply. Fury III	14.1mph	*M(D) F(P)	" "	Yes** Yes**	
			5	'73 Ply. Fury III	'73 Chevy Vega	27.4mph	*M(D) F(P)	" "	Yes** Yes**	
			6	'73 Chevy Impala	'73 Opel 1900	25.9mph	*M(D) F(P)	" "	Yes** Yes**	
/78	Accident Investigation Studies - Stage Rear Impact Collisions (Dynamic Science Report 3010-78-47)	R. Pirtle (Dynamic Science)	1	'71 Impala	'71 Pinto	17.6mph	50M(D)	L&S	-20	15° Impact angle w/pre-braking (.7g)
			2	'71 Impala	'71 Pinto	19.8mph	"	"	37	0° Impact angle w/pre-braking (.7g)
			3	SAE Bar.	'71 Pinto	21.5mph	"	"	32	
			4	'71 Impala	'72 Vega	25.4mph	"	"	18*	15° Impact angle w/pre-braking (.7g). *Looks like lab fixture in rear stopped seat back rotation.
			5	'71 Impala	'72 Vega	29.7mph	"	"	31	0° Impact angle w/pre-braking (.7g)
	(Seat Data in:) Test and Evaluation of Head Restraints, Seat Backs & Anchorages in Vehicles Subjected to Rear Impact Collision (PB 289 779)	R. Pirtle (Dynamic Science)	6	SAE Bar	'72 Vega	25.7mph	"	"	27	
			7	'71 Impala	'71 Pinto		"	"		No measurements made.
			8	"	'72 Pinto	22.5mph	"	"	27	0° Impact angle w/pre-braking (.4g)
			9	"	"	22.4mph	"	"	29	0° Impact angle offset 14"
			10	"	'72 Vega		"	"		No measurements made
			11	"	'71 Vega	24.8mph	"	"	16	0° Impact angle w/pre-braking(.4g)
			12	"	"	24.7mph	"	"	No data	0° Impact angle offset 11+"
			13	"	'74 Pinto	23.7mph	"	"	23	0° Impact angle w/prebraking (.6g)
			14	"	'71 Impala	18.7mph	"	"	27.5	0° Impact angle w/prebraking (.7g)
			15	"	'74 Pinto	16.7mph	"	"	No data Collected	0° Impact angle
			16	"	'76 Pinto	19.0mph	"	"		0° Impact angle w/prebraking (.6g)
			17	"	"	14.9mph	"	"	"	0° Impact angle
			18	"	'72 Pinto Sta.wagon	19.6mph	"	"	"	0° Impact angle w/prebraking (.6g)
			19	"	'76 Pinto Sta.wagon	17.4mph	"	"	"	0° Impact angle
11/80	Test and Evaluation of Volkswagen Type I Front Seat Integrity in Rear Impact Collisions (Dynamic Science Report No. 8340-80-192)	Pozzi (Dynamic Science)	1	'73 Impala	'72 VW I	0.7mph	50M(D) " (P)	L&S "	-35 -35	No seat damage other than back rest & rear frame yield.
			2	"	'74 VW I	0.4mph	" (D) " (P)	" "	-35 -35	" " " " "
			3	"	'72 VW I	0.5mph	" (D) " (P)	" "	-35 -35	" " " " "
			4	"	'74 VW I	0.7mph	" (D) 6 yr(P)	None None	-35 7	Driver side "medial hinge" broken.

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APPENDIX C.1 . NCAP REAR IMPACT TESTS 1979 MODEL "EAR VEHICLES

VEHICLE/SEAT DESCRIPTION			TEST DESCRIPTION			DUMMY RESPONSE			SEAT RESPONSE
Mode Yr	Manu- facturer	Model	-iver(D or RFP(P)	Belted(B) Unbelted (I	ΔV (MPH)	HIC	Pk Chest 's (-3ms	Residual Seat back Angle (deg's)	Remarks
1979	Chrysler	Cordoba	D	B	19	177.8	19.0	-35	Split bench seat.
			P	B	19	357.5	30.5	-35	
1979	Dodge	Aspen	D	B	20	258.4	26.0	-45	
			P	U	20	245.4	24.0	-45	Seat track broke, seat moved aft -2".
1979	Dodge	Colt	D	B	24.6	301.7	51.4	-40	Head contacted B-post 6 RFP head.
			P	B	24.6	327.8	3L.B	-45	Head contacted B-past & driver head.
1979	Dodge	Diplomat	D	B	18.6	263.7	18.3	-45	Bench seat moved 2" rearward.
			P	B	18.8	469.2	21.2	-45	
1979	Plymouth	Horizon	D	B	22.9	115.4	17.3	??	Both dummy heads impacted rear seat
			P	B	22.9	146.5	26.6	77	cushion during seat back recline.
1979	Ford	Fiesta	D	B	24.8	386.9	44.0	-45	
			P	U	24.a	359.7	33.0	-45	
1979	Ford	LTD Landa	D	B	18.7	140.0	10.4	-40	Both front seat backs bent inward and onto
			P	B	18.7	192.3	19.6	-40	rear seat cushion.
1979	Mercury	Monarch	0	B	19.9	1098.2	25.6	-45	Bench seat reclined allowing both dummy
			P	U	19.9	585.0	24.0	-45	heads to contact rear seat back.
1979	Mercury	Zephyr	D	U	22.5	341.0	23.0	-45	
			P	B	22.5	419.0	26.0	-45	
1979	Ford	Mustang	D	B	21.6	251.6	33.6	-40	Stopped by front seat backs striking rear
			P	B	21.6	105.8	28.0	-40	rest.
1979	Ford	T-Bird	D	B	17.5	52.5	15.9	-40	Both seat backs bent onto rear cushion.
			P	B	17.5 .	70.9	13.7	-45	
1979	londa	:ivic	D	B	25.3	219.9	32.9	-45	Passenger-side headrest torn off.
			P	B	25.3	245.9	34.3	-30	
1979	)atsun	?10	D	B	24.1	445.2	54.6	-45	Driver headrest became detached, both seats
			P	B	24.1	442.1	68.9	-40	moved 4" aft in tracks.
1979	3uick	:lectra	D	B	18.0	41.9	10.74	-45+	Both front seats moved 1" aft.
			P	B	18.0	94.L	11.56	-45+	
1979	3uick	?ivera S	D	B	18.2	35.3	10.4	-40	Split bench seat. Driver seat back broke.
			P	B	18.2	113.8	11.3	-45	
1979	:hevrolet	Camaro	D	B	19.3	214.0	17.5	-60	Both seats moved aft (Driver . 1.4"
			P	B	19.s	311.3	27.7	-45	Passenger 1").
1979	:hevrolet	:hevette	D	B	23.06	137.L	24.0	-45	Passenger seat moved 1" aft in tracks.
			P	B	23.06	309.9	29.4	-45	
1979	'ontiac	:atalina	D	B	19.0	415.0	14.0	-45	Bench seat back broke. Both heads contacted
			P	B	19.0	289.0	14.0	-45	rear seat back.
1979	'ontiac	;ran Prix	D	B	19.5	189.2	14.0	-60	Split bench seat. Both seat backs collapsed
			P	U	19.5	100.7	30.0	-45	Both heads hit rear seat back.
1979	'ontiac	;unbird	D	B	21.3	293.5	17.0	-50	Both front seats yielded at impact and the
			P	B	21.3	410.6	19.	-60	and the dummy heeds struck rear seat back.
1979	'oyota	:elica	D	B	21.9	210.0	27.0	-60	Both front seat backs yielded on impact.
			P	U	21.9	286.0	30.0	-60	Both dummy heeds struck rear seat back.
1979	'oyota	:orolla	D	U	23.5	623.0	36.0	-45	Passenger head contacted rear seat back
			P	B	23.5	1147.0	42.0	-45	support bracket.
1979	N	abbit	D	B(VWRA)	23.8	114.5	17.0	-40	Both bucket seat backs yielded.
			P	B(VWRA)	23.8	102.8	17.0	-45	
1979	'olvo	'44DL	D	B	20.6	51.1	13.4	-45	Both seat backs yielded at impact.
			P	U	20.6	210.2	18.4	-45	Both heads struck back of rear scat.
1979	'ord	into	D	B	22.3	288.6	47.0	-45+	Both seat backs yielded at impact. Both
			P	B	22.3	303.2	76.0	-45+	heads strut back of rear seat.
1979	hrysler	ewport	D	B	18.7	19b.o	13.7	-60	Bmh seat. Bench seat back yielded, both
			P	B	18.7	138.2	12.9	-60	dummies reclined.

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B

TABLE'1 - SUMMARY OF STATIC BEAT PULL TESTS

SEAT DESCRIPTION			SEAT PERFORMANCE				
MODEL YR.	MANUFACTURER	MODEL	STIFFNESS (lbf/in.)[1]	STRENGTH (lbf.)[2]	ABSORBED ENERGY (ft. lbs)[3]	REMARKS	TEST CONDUCTED BY:
	MG	-			116.6		CSE
'64	AMC	RAMBLER	166.5	560.0	93.6		CSE
'64	VW	TYPE I	137.9	620.0	2a.7		CSE
	TRIUMPH	-			174.3		CSE
'64	PONTIAC	LEMANS	265.0	590.0	69.7		CSE
'65	RENAULT	DAUPHINE	73.2	455.0	100.1		SMRY
'66	CHEVROLET	CHEVELLE	103.4	505.0	170.5		SEVERY
'66							
'66	DATSUN	DART	1685.1	325.0	323.2 174.2		SEVERY SEVERY
'66	FORD	CORTINA	106.6	415.0	114.1		SEVERY
'66	FORD	FALCON					
		RANCHERO	106.0	615.0	244.6	One side of split bench seat	SEVERY
'66	PLYMOUTH	BARRACUDA	121.2	850.0	233.7	One side of split bench seat	SEVERY
'66	VW	95	144.9	426.0	175.4		SMRY
'66	VOLVO	TYPE III	79.4	640.0	204.9		SMRY
'66		544	169.0	730.0	416.5	Friction clutchets/back pivot adjusted for maximum torque	
							SEVERY
'67	FIAT	850	137.9	475.0	163.6		SMRY
'67	PLYMOUTH	BARRACUDA	105.3	680.0	374.2	Split bench seat, one side	SEVERY
'67	RENAULT	R10	66.7	490.0	191.2		SEVERY
'67	DATSUN	TYPE II	102.6 115.6	360.0	x287.7[4]		SEVERY
'68							SEVERY
	FORD						
'68	SAAB	MUSTANG	160.0 06.9	787.0	278.4		SEVERY
'68 '66	VOLVO	144	137.9	476.0	2'71.1		SEVERY
'68		TYPE I	103.6	700.0	509.8		SEVERY
'69	VW		76.4	WI.0	N/A*		CSE
'69	MERCURY	COUGAR	40.4[4]	716.0	N/A		CSE
'70	OPEL	1900	00.9	570.0	N/A		SEVERY
'70	RENAULT	R10	52.6	525.0	N/A		SEVERY
'70	TOYOTA	COROLLA	46.6	310.0	N/A		SEVERY
	SUBARU		55.5	300.0[5]	N/A		SMRY
'70	DATSUN	610	142.9	365.0	N/A		SMRY
70	RAT	850	95.2	873.0	N/A		SEVERY
'70	AUSTIN	AMERICA	222.2	830.0	N/A		SMRY
'70	AMC	GREMUN	285.7	14ca.o'	N/A		SEVERY
	CHEVROLET						CSE
'70	VW	TYPE E CARLO	239.0	778.0	243.3		CSE
'71	PLYMOUTH	DUSTER	162.4	830.0	535.9[4]		CSE
'71	VOLVO	144	222.2	630.0	373.4	Friction clutch at s/back pivot adjusted for maximum torque	CSE
							CSE
'73	CHEVROLET	PINTO	169.6	720.0	N/A 373.2		SEVERY
	VW						CSE
'74	CHEVROLET	MONTE CARLO	285.7	1630.0	243.3		CSE
	FORD						CSE
'76	CHEVROLET	MAVERICK CARLO	57.3	346.6	145.9	Swivel bucket seat	CSE
							CSE
'76	DATSUN/LET	B210/VETTE	169.5	630.0	267.6		CSE
'76	VOLVO	242DL	176.6	1113.0	2942	Seat broke just prior to reaching 45 degrees	
'76	ROLLS ROYCE	S. SHADOW	45.9	500.0	194.9		CSE
77	VW	RABBIT	444.4[4]	1160.0	N/A		CSE
		CAMARO					CSE
'82	CHEVROLET	TERCEL	100.0	520.0	290.6		CSE
'02	TOYOTA		146.0	413.0	164.3		C-SE
							CSE
'84	FORD VOLVO	700 SERIES	60.7	1700.0	269.4		CSE
	CHEVROLET						CSE
'86		STANZA UM	77.2	588.0	258.7		CSE
	NISSAN						CSE
'86	SUBARU	STATION WAGON	66.3	827.0	399.3		CSE
'86	VW	JETTA	78.4	866.0	336.9		CSE
'86	BMW	733I	62.6	591.0	194.6		CSE
'88	MERCEDES	300	126.2	1144.0	299.7		CSE
AVERAGE VALUES			134.6	660.2	256.9		
[4]HIGHEST VALUE			606.1	1400.0	535.9		
[5]LOWEST VALUE			40.4	300.0	87.7		

*NOT AVAILABLE
[1]AVERAGE OVER FIRST 200 LBFS
[2]MAXIMUM FORCE DURING DEFLECTION, STOPPED AT 45 DEGREES
[3]ENERGY NOT CALCULATED BEYOND 46 DEGREES

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APPENDIX C.2 · NCAP REAR IMPACT TESTS · 1980 MODEL YEAR VEHICLES

VEHICLE/TEST DESCRIPTION			TEST DESCRIPTION			DUMMY RESPONSE		SEAT RESPONSE	
Mode Yr	Manu-facturer	Model	·iver(D) or RFP(P)	Belted(B) Unbelted (U)	ΔV (MPH)	HIC	Pk Chest :'s (3-ms)	Residual Seat Back Angle (deg's)	Remarks
198C	AMC	Concord	D P	U B	19.9 19.9	78.9 89.1	16.0 12.2	N/A -45	Driver seat separated from tracks. Both heads struck rear seat back.
198C	Dodge	Mirada	D P	B B	19.6 19.6	·· ··	·· ·	-45 -45	Both seats moved 1.5" aft in tracks. Split bench seat.
1980	Mercury	Cougar	D P	B B	20.1 20.1	A.0 57.0	12.9 13.0	-60 -60	Bench seat moved 3" aft. Track severely buckled. Left track 80% split.
1980	Subaru	GL	D P	B B	23.5 23.5	· ··	·· ··	·· ··	Both dummy heads contacted rear seat back.
1980	Honda	Civic 1500DX	D P	B B	24.7 24.7			-45 -45	Left front seat moved 3" aft. Outboard anchor of RFP seat torn from floor.
1980	Chevrolet	Citation	D P	B B	21.4 21.4	171.3 255.8	18.0 31.0	-45 -45	Bench seat. Seat back reclined.
1980	Honda	Prelude	D P	B U (Belt detache	23.5 23.5			-50 -60	Passenger forehead struck backlight. Driver seat moved 4.5" aft. Driver head hit rear seat back.
1980	Datsun	310	D P	B B ·	24.2 24.2	·· ··	·· ··	-45 ·	
1980	Renault	LeCar	P P	B B	2b.7 2c.r	· ··	 ··	-45 ··	
1980	Datsun	200SX	D P	B B	22.2 22.2	·· ··	·· ··	?? ??	Both dummies hit rear seat back.
1980	Mazda	626	D P	B B	22.3 22.3	·· ··	·· --	-45 -45	Both seat backs bent rearward onto rear seat
1980	VW	Rabbit Convertibl	D P	B B	23.4 23.4	·· ··	·· ··	-45 -45	Both dummies hit rear seat back with head. Seat backs bent onto rear seat cushion.
1980	Toyota	Corolla Deluxe	D P	B B	23.5 23.5	·· ··	·· ··	?? ??	Both dummies hit rear seat back. Passenger dummy head hit B-pillar.
198C	Oldsmobile	Cutlass	D P	B B	19.3 19.5	·· ··	·· ··	-60 -60	Split bench seat. Both dummies contacted rear seat back.
198C	Fiat	Strada	D P	B B	23.8 23.8	·· ··	·· ··	77 ??	Both dummy heads contacted rear seat back.

APPENDIX c.3 . NCAP REAR IMPAC TESTS 1961 MODEL YEAR VEHICLES

VEHICLE/SEAT DESCRIPTION			TEST DESCRIPTION			DUMMY RESPONSE		SEAT RESPONSE	
Mode Yr	Manu-'acturer	Model	river(D or RFP(P)	Belted(B) ·belted (U)	ΔV (MPH)	HIC	Pk Chest G's (·3ms)	Residual Seat Back Angle (deg's)	Remarks
1981	AMC	Spirit	D P	B B	21.6 21.6	-- --	-- --	-60 -45	Both dummy heads hit rear seat back.
1981	Chrysler	Imperial Specialit	D P	. .	11.0 18.0	-- --	-- --	-40 -40	Split bench seat. Both dummy heads contacted rear seat back.
1981	Dodge	Aries	D P	. B	22.8 22.8	Dummies ··	instrumented --	-80 -80	Bench seat came off tracks.
1981	Honda	Civic	D P	B B	24.1 24.1	·· ··	-- --	-45 -64	Both dummy heads contacted rear seat back.
1981	Catsun	810	D P	. B	20.7 20.7	·· ··	-- --	-45 -45	Head restraints became detached.
	Renault	18i Deluxe	D P	. B	23.4 23.4	·· ··	-- --	-60 -60	Both seat backs reclined to rear seat cushion. Both heads contacted rear seat.
1981	Mazda	GLC Custom	D P	. B	24.2 24.2	·· --	-- --	-64 -60	Both dummy heads made contact with th. rear rear back.
1981	Toyota	Cressida	0 P	B(Passive B(2-pt)	20.8 20.8	·· ··	-- --	-45 -45	Both dummy heads hit rear seat back.
1981	Toyota	Starlet	D P	B B	25.0 25.0	·· ··	-- ·	-45 -4s	Both seat backs bent onto rear cushion. Bo heads hit rear seat back.
1981	VW	Jetta	D P	B(VWRA) B(VWRA)	23.1 23.1	·· ··	-- --	-60 -60	Both dummy heads hit rear seat back.
1981	Chevy	Cavalier	D P	·· ··	22.7 22.1	·· ··	-- --	?? ??	Both dummies impacted rear seat back cushic
1981	Plymouth	Sapporo	D P	B B	21.3 21.3	·· ··	-- --	-50 77	Both dummy heads hit rear seat back. Passenger seat pulled loose.
1981	Isuzu	I-Mark	D P	B B	23.6 23.6	·· ··	-- --	-45 -60+	Seat backs bent rearward. Passenger seat twisted inboard. Passenger head hit roof healiner. Driver head hit rear seat back.
1981	Mercury	Lynx	D P	. B	23.7 23.7	·· ··	-- --	-45 -45	Passenger seat right rail separated from track. Both heads contact rear seat back.

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APPENDIX C

Eighteen 30 - 39 MPH Delta-V

Rear Impact - NASS 1988 - 1990

OBSERVATIONS

EIGHTEEN 30-39 MPH DELTA V REAR IMPACTS - NASS 1988-1990

- NINE OF THE EIGHTEEN CASES INVOLVED MULTIPLE IMPACTS
- TWENTY-NINE OCCUPANTS WERE INVOLVED IN THE EIGHTEEN CASES OF WHICH NINETEEN WERE RESTRAINED - HOWEVER, TWO BELT SYSTEMS RELEASED DURING THE CRASH EVENT - ONE BROKE AND THE OTHER WAS NOT PRORERLY LATCHED
- OUT OF 25 OCCUPIED FRONT SEATS - 21 YIELDED
- TWO CARS BURNED FOLLOWING THE CRASH EVENT - ONE OCCUPANT DIED IN THE FIRE
- OF THE EIGHTEEN CARS INVOLVED, THREE HAD A FRONT BENCH SEAT
- ONE VEHICLE WAS INVOLVED IN TWO REAR IMPACTS IN THE SAME CRASH EVENT
- THE MOST FREQUENTLY INJURED BODY PART WAS THE HEAD AND FACE - THE HIGHEST SEVERITY INJURIES WERE INFLICTED TO THE HEAD AND CHEST
- THE MOST FRAQUENTLY RECORDED PROBABLE SOURCE OF INJURY WAS THE STEERING WHEEL FOLLOWED BY THE SEAT BACK, HEADREST! AND FLYING GLASS - HOWEVER, THE NUMBER OF NONCONTACT INJURIES WERE EQUAL TO THE NUMBER OF INJURIES CAUSED BY THE STEERING WHEEL
- IN THIS SMALL SAMPLE, THE INJURY RATE FOR AIS 2 AND GREATER INJURIES FOR RESTRAINED OCCUPANTS IS 26%, WHILE THE INJURY RATE FOR UNRESTRAINED OCCUPANTS IS 50%, PROVIDING A SEAT BELT EFFECTIVENESS OF 48%

CASE 88-43-002

CASE VEHICLE: 1984 Subaru GL (V2)
CASE VEHICLE WEIGHT: 2190 lbs.
CASE VEHICLE DELTA V: 30 mph

CIRCUMSTANCES

Vehicles 1 and 2 were traveling on a one way, four lane street approaching an intersection with a traffic signal. Both vehicles. were in the same lane. As V2 approached the intersection the driver of V1 applied his brakes before striking V2. V1 underrode V2. V2 continued down the street striking a "No Parking" sign and a utility pole.

Both occupants were using lap/shoulder belts.

Both front bucket steat back folding locks failed and the seat backs rotated rearward and came to rest on top of the rear seat cushion. The driver's seat rotated approximately 45 degrees, and the passenger seat approximately 30 degrees. The front seats had adjustable headrests with no damage reported.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 22
HEIGHT: 65 in.
WEIGHT: 116 lbs.
RESTRAINT USED : Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Contusion, chest	1	1	Steering Wheel
Whiplash, neck	1	3	Coded Fire - Not obvious from report or photos

SEATING POSITION: RIGHT FRONT FASSENGER
SEX: Male
AGE: 31
RESTRAINT USED : Lap/Shoulder Belt

CASE 88-43-002(CONT)

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Contusion, face	1	7	Unknown
Laceration (4 in.), face	2	7	Unknown
laceration, wrist	1	7	Unknown

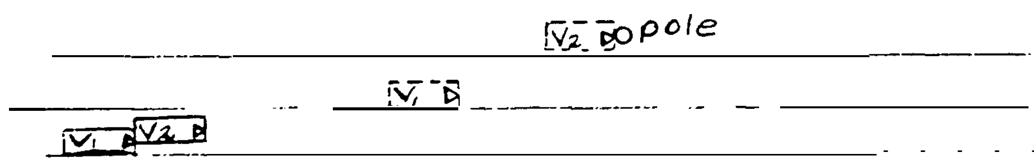
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (3) Noncontact Injury, and (7) Unknown source

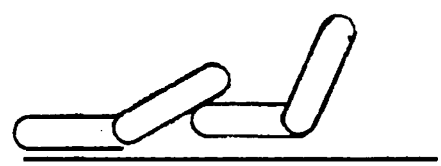
SEAT PERFORMANCE
Both the driver and front seat passenger's seat back locks failed.

MISC: INFORMATION

V1 - 1978 Chry Cordoba - Weight 4151 lbs. - Delta V 17 mph

CASE 002





SEATS
FOLLOWING CRASH

CASE 88-80-026

CASE VEHICLE: 1985 HONDA PRELUDE (V2)
CASE VEHICLE WEIGHT: 2219 lbs.
CASE VEHICLE DELTA V: 35 mph

CIRCUMSTANCES

V3 stoped suddenly on highway after missing a turn. V2, following, slowed to a stop and was struck from behind by V1. V2 was pushed into the rear of V3.

The restrained driver of the case vehicle received minor injuries and was transported to the hospital and released. She lost one day of work.

The driver's seat was. rotated approximately 45 degrees. rearward by the occupant. The driver's seat back was resting on top of the rear seat cushion.

The front seats. in the case vehicle were bucket seats with folding backs, and the headrests were adjustable with no reported damage.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 27
HEIGHT: 55 in.
WEIGHT: 125 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Contusion, Face	1	1	Steering Wheel
Strain, Neck	1	2	Steering Wheel
Contusion, Thigh	1	1	Steering Wheel
Contusion, Knee	1	1	Left Instr. Panel
Contusion, Shoulder	1	1	Seat Belt

(*) D/I - Direct/Indirect Injury - (1) Direct Contact Injury, and (2) Indirect Contact Injury

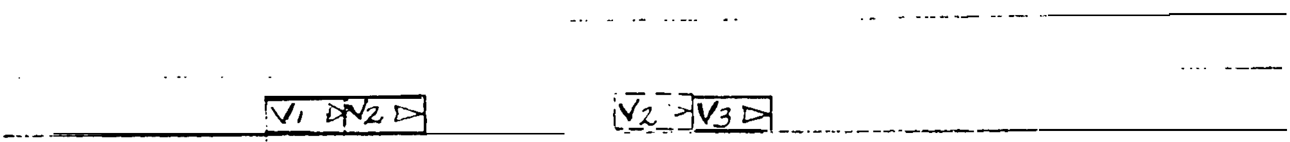
SEAT PERFORMANCE
Driver Seat - Deformed by impact of occupant from front

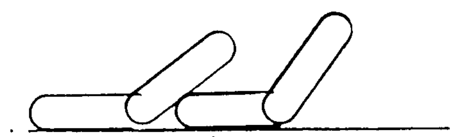
MISC INFORMATION
V1 - 1977 BMW 530i
V3 - 1987 Isuzu Imark

CASE 88-80-026(CONT)

Note: This vehicle underwent a frontal impact following the rear impact possibly accounting for the steering wheel injury.

CASE 026





Seats
FOLLOWING CRASH

CASE 88-49-035

CASE VEHICLE: 1976 AUDI 100 (V2)
CASE VEHICLE WEIGHT: 2790 lbs.
CASE VEHICLE DELTA V: 32 mph

CIRCUMSTANCES

Vehicle 2 was traveling in the third lane of a four lane freeway. V2 stopped and V1, also traveling in the third lane, struck V2. V2 sustained severe rear impact damage.

The restrained driver of V2 received numerous injuries, some of unknown sever i ty . He was hospi tal ized for seven days and off work for 10 days.

The rear seat was pushed forward by intrusion from V1 and the back of the driver's seat was rotated rearward approximate1 y 45 degrees by the impact force of the driver,

The front seats in the case vehicle were bucket seats., and the headrests were adjustable. The driver's headrest was damaged while the right front seat passenger's was. not.

RESTRAINT AND INJURIES

CASE VEHICLE
0SEATING POSITION: Driver
SEX: Male
AGE: 2 7
HEIGHT: 74 in.
WEIGHT: 180 lbs.
RESTRAINT USED: Lap/Shou 1 der Bel t

INJURIES	AIS	D/I(*)	POTENT I AL SOURCE
Laceration,abdomen	2	2	Seat Back
Concussion, head	2	1	Rear Header
Bl un t Trauma	7	7	Seat Be1 t
Laceration,face	1	1	Steering Wheel rim

(*) D/I - Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, and (7) Unknown Source

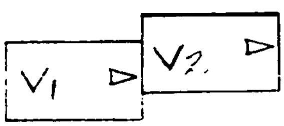
SEAT PERFORMANCE
Dr iver - Coded deformed by impact of occupant from front

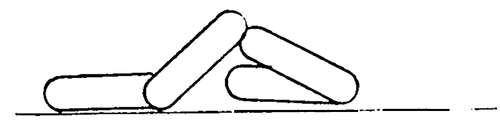
CASE 88-49-035(CONT)

MISC INFORMATION

V1 - 1982 Ford F150 Pickup - Weight 4040 lbs. - Delta V 22 mph

CASE 035





SEATS
FOLLOWING CRASH

CASE 88-7 l-042

CASE VEHI CLE: 1983 Ford LTD (V2)
CASE VEHICLE WEIGHT: 3092 lbs.
CASE VEHICLE DELTA V: 32 mph

CIRCUMSTANCES

Vehicles 1 and 2 were traveling in the same direction on a four lane divided state highway with a slower moving vehicle in between them. V1 passed the slower moving vehicle. As V1 is. passing, its left front wheel contacted the curb of an island separating the two directions of traffic. V1 drifted to the right lane and contacted V2 in the rear. Both V1 and V2 continued on and came to rest on a curbed isl and.

The driver of the case vehicle was using the lap/shoulder bel t but the bel t was not latched properly and came unbuckled during the col 1 i son. She recieved a minor head injury and was hospitalized three days. Her seat rotated rearward approximate1 y 45 degrees during the crash,

The front seats. in the case vehicle were bucket seats with folding seat tacks, and the headrests were adjustable with no reported damage.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITI ON: Driver
SEX: Fema 1 e
AGE: 49
HEIGHT: 66 in.
WEIGHT: 148 lbs.
RESTRAINT USED : Lap/Shou 1 der Bel t - Improper1 y 1 atched and came unbuckl ed during crash.

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Strain, neck	1	2	Headrest
Concussion, head	2	1	Headrest
Laceration, face	1	7	Unknown
Laceration, shoulder	1	1	Seat Back
Laceration, head	1	1	Headrest
Abrasion, Whole Body	1	7	Unknown

(*) D/I - Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, and (7) Unknown Source

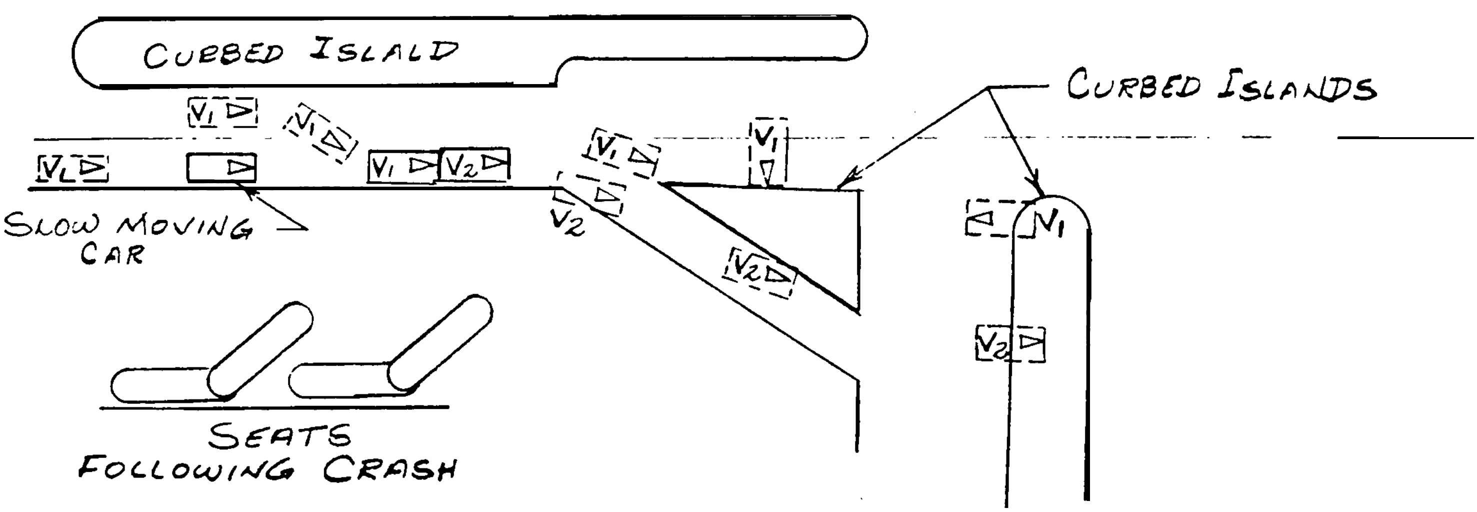
CASE 88-i 1-042(CONT)

SEAT PERFORMANCE
Driver - Seat back folding locks failed and was deformed by occupant from front - rotation about 45 degrees.

MISC: INFORMATION

V1 - 1976 Buick Skylark - 3391 lbs. - Delta V 29 mph

CASE 042



CASE 90-2-062

CASE VEHI CLE: 1977 Ford LTD (V2)
CASE UEHI CLE WE1 GHT: 4144 lbs.
CASE VEHICLE DELTA V: 35 mph

CIRCUMSTANCES

V2 was. stopped to make a left turn and was struck in the rear by V1, a pickup truck towing a 3200 lb. trailer. V2 burst into f1ames killing the driver and his dog. The unrestrained driver received 3rd and 4th degree burns over the whole body. The cause of death was asphyxiation by carbon monoxide.

The front seat in the case vehicle was a bench seat with folding seat back, and the headrests were adjustable with the driver's reported damaged.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 75
RESTRAINT USED : None

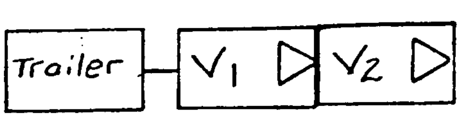
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Burns, Whol e Body	6	1	Asphyxiation

(*) D/I - Direct/Indirect Injury - (1) Direct Contact Injury

SEAT PERFORMANCE
Driver's - Seat back broken - Deformed during occupant impacting seat back.

MISC INFORMATION
V1 - 1989 Chevy 3500 Pickup - Weight 4269 lvs. towing a 3180 lb, trailer.

CASE 062



CASE 90-73-067

CASE VEHICLE: 1982 Dodge Colt (V1)
CASE VEHICLE WEIGHT: 2000 lbs.
Case Vehicle DELTA V: 32 mph.

CIRCUMSTANCES

Vehicle 1 was traveling behind vehicle 3 in the same lane. V1 rear ended U3. V1 rotated clockwise and was struck in the rear by V2 heading in opposite direction. V2 sustained frontal damage. V3 continued down the street in a counter clockwise rotation and rolled over.

The unrestrained driver in the case vehicle sustained a chest fracture from the steering wheel. The accident report states the driver's seat was deformed by the occupant, but slides. show little deformation. The rear seat was pushed forward 27 - 29 in. by the rear impact.

The front seats in the case vehicle were bucket seats with the headrests integral with the seat with no damage reported.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING LOCATION: Driver
SEX: Male
AGE: 35
RESTRAINT USE: None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Laceration! Face	1	1	Windshield
Laceration, Head	1	7	Unknown
Contusion, Head	2	7	Unknown
Fracture, Chest	3	1	Steering Wheel

(*) - Direct/Indirect Injury - (1) Direct Contact Injury, (7) Unknown Source

SEAT PERFORMANCE
Driver's seat was forced forward by intrusion from the rear hatch area.

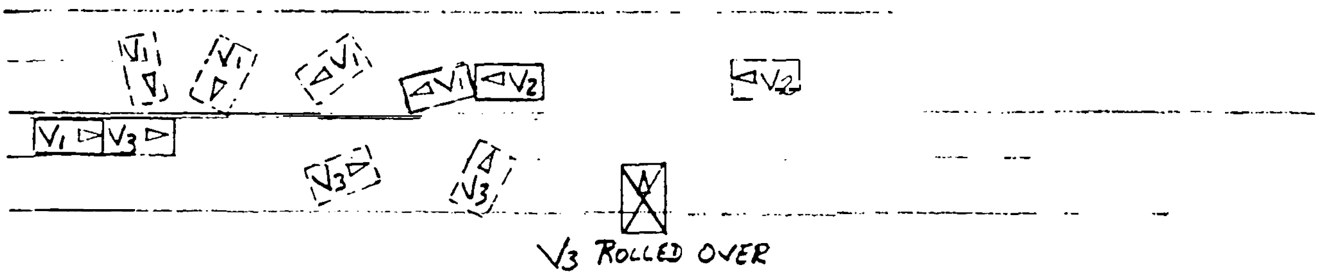
MISC INFORMATION

v 2 - 1979 Chevy Monte Carlo - 3249 lbs. - Delta V 20 mph
v 3 - 1989 Mercury Topez - 2606 lbs. - Delta V 12 mph

CASE 90-73-067(CONT)

Note: Since the case vehicle went through multiple impacts., frontal first, it would be hard to determine how and when the driver contacted the steering wheel and windshield.

CASE 067



CASE 89-78-094

CASE VEHICLE: 1982 Subaru GL Hatchback (V2)
CASE UEHI CLE WE1 GHT: 2378 Pounds
CASE VEHICLE DELTA V: 32 mph

CIRCUMSTANCES

Vehicle 2 was stopped, waiting to make a left turn, at a 3-way intersection on a two-way street. Vehicle 1 struck vehicle 2 from behind. Both vehicles were towed and both occupants were taken to the hospital and released. The driver lost 4 days work as a result of the accident and the front seat passenger one.

During the impact both seats were rotated rearward approximate1 y 45 degrees .

Both occupants were using the lap/shoulder bel ts provided.

The driver received minor injuries and the front seat passenger received no injury.

The seats in the case vehicle were bucket seats with folding backs. The headrests were integral with no damage reported.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Femal e
AGE: 21
HEIGHT: 64 in,
WEIGHT: 130 lbs.
RESTRAINT USED: Lap/Shoulder Bel t

INJURIES	AIS	D/I (*)	PROBABLE SOURCE
Laceration, head	1	1	"B" Pi 1 lar
Contusion, Shoulder	1	1	Left "A" Pi 11 ar
Strain, neck	1	3	Unknown, possibl y head rest, al though i t was repor ted no damage to head rest

(*) D/I - Direct/Indirect Injury - (1) Direct Contact Injury, and (3) Noncontact Injury.

CASE 89-78-094(CONT)

SEAT LOCATION: Right Front
SEX: Female
AGE: 35
HEIGHT: 62 in.
WEIGHT: 120 lbs.
RESTRAINT USED: Available Lap/Shoulder Belt

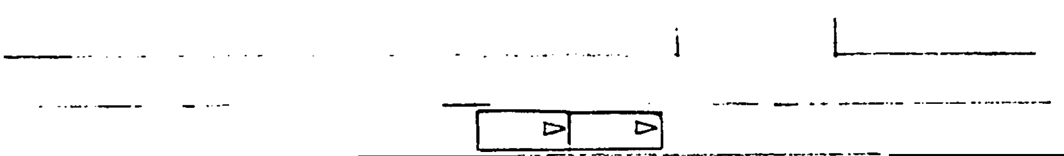
This occupant received no injury.

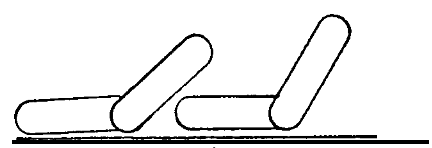
SEAT PERFORMANCE

Both seats coded deformed by intrusion of the rear deck and deformed by impact of the occupant from front - The driver's seat appears to be rotated approximately 45 degrees and the right front passenger's seat about 30 degrees.

MISC INFORMATION
V1 - 1988 Suzuki Samurai - Weight 2291 lbs. - Delta V 33 mph

CASE 094





Seats
Following Impact

CASE 88-47-222

CASE UEHICLE: 1977 Ford LTD (V2)
CASE UEHICLE WEIGHT: 4414 lbs.
CASE UEHICLE DELTA V: 35 mph

CIRCUMSTANCES

Both vehicles V1 and V2 were traveling in the same direction on a two lane highway. V2 stopped to make a left turn. V1 struck V2 in the rear. V2 was knocked forward and onto the left shoulder where fire broke out completely burning back 2/3's of vehicle. The unrestrained driver received a minor injury. He was taken to the hospital and released. He lost no time from work.

The driver's seat was deformed by the occupant! approximately 45 degrees rotation, with the seat back comming to rest on the rear seat cushion.

The front seats in the case vehicle were bucket seats with folding backs.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 33
HEIGHT: 70 in.
WEIGHT: 200 lbs.
RESTRAINT USED: None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Laceration, Face	1	1	Mirror

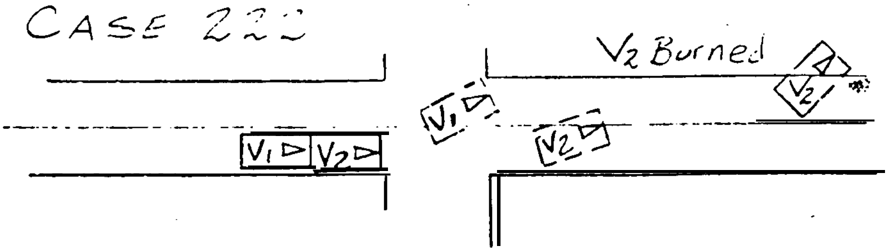
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury

SEAT PERFORMANCE
Driver - Deformed by occupant - later burned

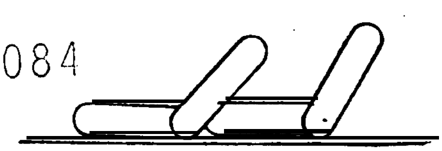
MISC INFORMATION

V1 - 1988 Toyota/4 Runner - Weight 3206 lbs. - Delta V 48 mph

CASE 222



084



Seats Following Impact

CASE 90-9-067

CASE UEHI CLE: 1983 Dodge Omni (V2)
CASE UEHI CLE WEI GHT: 2302 1 bs.
CASE UEHI CLE DELTA V: 30 mph

CI ROUMSTANCES

Vehicles 1 and 2 were east bound on a state road, V1 contacted V2 at the rear causing serious damage to the rear of the car.

The driver of the case vehicle was restrained by a lap/shoulder belt. He refused any treatment.

The driver's seat was was. slightly deformed, approximately 15 degrees, during the accident by the occupant.

No points of occupant contact were noticed.

The front seats in the cae vehicle were bucket seats with folding backs. The headrests were adjustable with no damage reported.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SEX: Male
AGE: 22
HEIGHT: 66 in.
WEIGHT: 150 lbs.
RESTRAINT USED: Lap/Shoulder Bel t

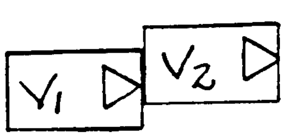
Injuries unknown - Occupant refused treatment

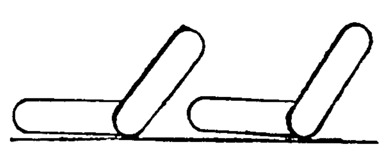
SEAT PERFORMANCE
Driver - Slightly deformed by occupant - about 15 degrees.

MISC INFORMATION

V1 - 1983 Honda Accord - Weight 2514 lbs. - Delta V 27 mph

CASE 067-9





Driver's seat slightly deformed -
~15° Beyond normal

CASE 89-46-070

CASE UEHI CLE: 1985 Honda Civic LRX (V2)
CASE UEHI CLE WEI GHT: 1923 lbs.
CASE UEHI CLE DELTA V: 33 mph

CIRCUMSTANCES

Uehicl es V4, U3, and V2 had stopped at a traffic light. V1 struck V2 and pushed it into V3 which in turn struck U4. V2 was underriden by V1 and rotated slightly clockwise by V1 before striking V3. The properly restrained driver received injuries from contact with the steering wheel. She 1 os t 15 days of work as a result of the accident,

There was severe damage to the rear of the car but no reported seat failure.

The front seats in the case vehicle were bucket seats with folding seat backs. The headrests were adjustable. The driver's headrest was damaged during the crash while the passenger's was. not.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SEX: Fema 1 e
AGE: 37
HEIGHT: 66in.
WEIGHT: 110 1 bs,
RESTRAINT USED : Lap/Shou 1 der Bel t

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Concussion , Head	2	1	Steering Wheel
Fracture, Neck	2	3	Noncontact
Strain, Neck	1	3	Noncontact
Contusion, Face	1	1	Steering Wheel
Contusion, Chest	1	1	Seat Bel t
Strain, Back	1	1	Seat Back
Contusion, Abdomen	1	1	Seat Bel t
Knee, Contusion	1	1	Lt. Instr. Panel
Ankle (Lt), Contusion	1	1	Foot Controls
Ankle (Lt), Contusion	1	2	Foot Controls
Ankle (Rt), Contusion	1	1	Foot Control s
Ankle (Rt), Contusion	1	2	Foot Control s

(*) D/I - Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, and (3) Noncontact Injury

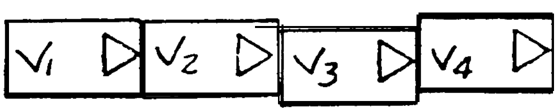
CASE 89-46-070 (CONT)

SEAT PERFORMANCE
Driver - No reported failure

MISC INFORMATION
V1 - 1987 BMW 324 - Delta V 21 mph - Weight 3031 lbs.
V3 - 1984 Nissan Sentra
V4 - 1987 Chry. LeBaron

Note - Since V2 struck V3, steering wheel injuries could be result of the frontal impact and not necessarily rebound from the rear impact.

CASE 070



CASE 89-12-091

CASE VEHICLE: 1980 Buick Skylark (V2)
CASE VEHICLE WEIGHT: 2475 lbs.
CASE VEHICLE DELTA V: 35 mph

CIRCUMSTANCES

Vehicle 2 was stopped at a traffic light when struck by vehicle 1. The rear of V2 underwent severe damage. The unrestrained driver of the case vehicle was seriously injured and was still hospitalized when the accident report was released. He sustained four broken ribs and a broken clavicle. The front seat passenger recieved minor injuries, was treated at a hospital, and lost seven days work.

Both front seats were deformed rearward by impact force loaded by the occupants. The bench seat rotated approximately 50 degrees.

The headrests in the case vehicle were integral with with the seats with no damage reported.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 62
WEIGHT: 190 lbs.
HEIGHT: 72 in.
RESTRAINT USED: None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Contusion, Chest	3	7	Unknown
Fracture, Shoulder	2	7	Unknown
Fracture, Ribs and Clavical	2	1	Left Arm Rest

SEATING POSITION: Right Front Passenger
SEX: Female
AGE: 54
HEIGHT: 65 in.
WEIGHT: 194 lbs.
RESTRAINT USED: None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Strain, Neck	1	2	Head rest
Contusion, Pelvis	1	1	Seat Back
Contusion, Whole body	1	7	Unknown

CASE 89-12-091(CONT)

(*) D/I - Direct/Indirect Injury - (1) Direct Contact Injury - (2) Indirect Contact Injury, and (7) Unknown Source

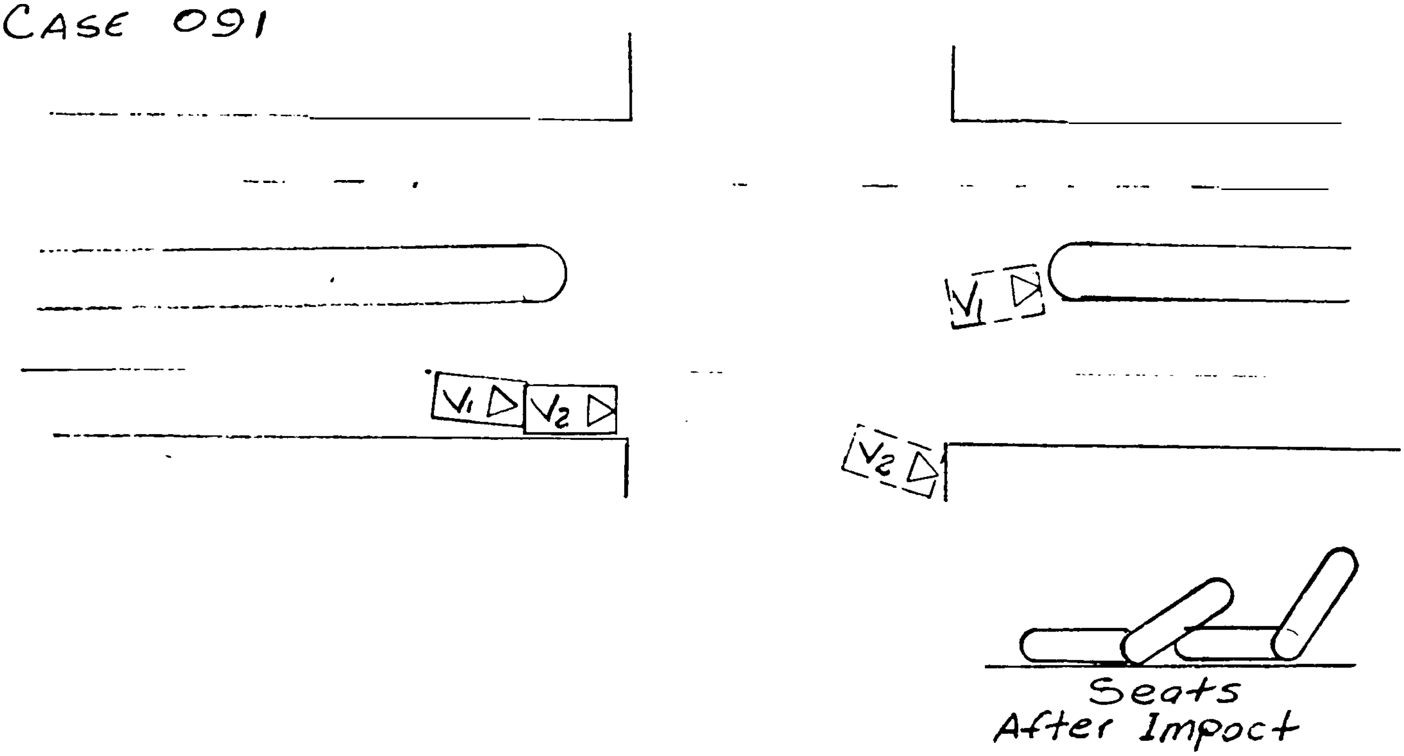
SEAT PERFORMANCE

Bench seat - Seat adjusters fai 1 ed - seat anchors failed - seat deformed by occupants - the seat rotated about 50 degrees.

MI SC' INFORMATION

V1 - 1987 GMC JIMMY - 3298 1 bs. - Del ta V 29 mph

CASE 091



CASE 90-47-100

CASE VEHICLE: 1988 FORD TEMPO (V2)
CASE VEHICLE WEIGHT: 3167 lbs
CASE VWEHICLE DELTA V: 31 mph

CIRCUMSTANCES

Vehisles 1 and 2 were traveling on a bridge. The front of V1 struck the back of V2. V1 then struck a curb on the right and V2 struck the bridge rail and rotated and was struck from behind by the front of V3. V2 had two rear impacts to the same area. First impact was minor, the second impact was most severe.

There were four occupants in the case vehicle. The front seat occupants were restrained by the lap/shoulder belts, the left rear occupant by the lap belt, and the right rear occupant was unrestrained. All occupants received minor (coded AIS 1) injuries, although the left rear occupant's injury was coded as a fractured face.

The right front seat was rotated rearward approximately 35 degrees by its occupant during the crash event.

The front seats in the case vehicle were bucket seats with folding seat backs. The headrests were adjustable with no damage reported.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 23
HEIGHT 65 in.
WEIGHT: 175 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Strain, Back	1	3	Impact Force

SEATING POSITION: Right Front Passenger
SEX: Female
AGE: 32
HEIGHT: 66 in.
WEIGHT: 120 lbs.
RESTRAINT USED: Lap/Shoulder Eelt

CASE 90-47-100(CONT)

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Contusion, Shoulder	1	1	Seat Back
Contusion, Face	1	1	Sunvisor
Strain, Back	1	3	Impact Force

SEATING POSITION: Left Rear Passenger
SEX: Male
AGE: 34
HEIGHT: 68 in.
WEIGHT: 190 lbs.
RESTRAINT USED: Lap Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Contusion Back	1	1	Seat Back
Laceration, Head	1	3	Flying Glass
Fracture, Face	1	1	Back of front seat

SEATING POSITION: Right Rear Seat
SEX: Female
AGE: 26
HEIGHT: 59 in,
WEIGHT: 150 lbs.
RESTRAINT USED: None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Abrasion, Knee	1	1	Seat Back
Abrasion, Leg	1	1	Seat Back
Strain, Back	1	3	Impact

(*) D/I - Direct/Indirect Injury - (1) Direct Contact Injury, and (3) Noncontact Injury

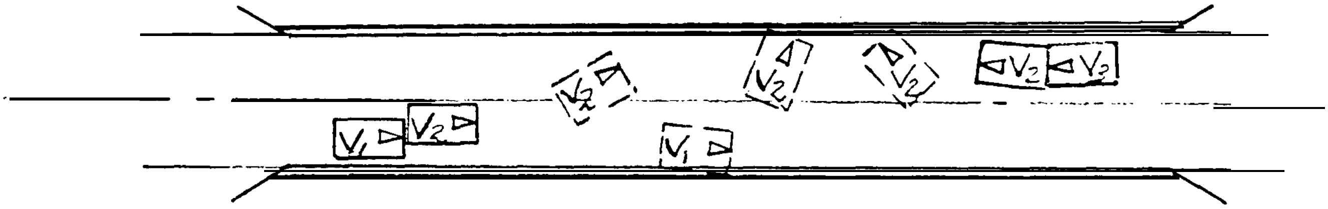
SEAT PERFORMANCE

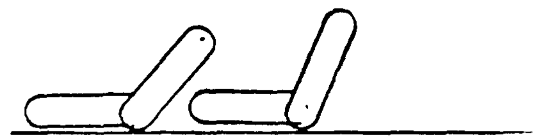
Driver - No recorded failure
Right Front Passenger - Deformed by occupant
Left Rear Passenoer and Right Rear Passenger - Intrusion from rear

MISC INFORMATION

V1 - 1989 Ford Crown Victoria
v 3 - 1987 Dodge Caravan

CASE 100





Seats
Following Crash

CASE 88-44-113

CASE UEHI CLE: 1985 FORD EXP (V2)
CASE VEHI CLE WEI GHT: 2212 lbs.
CASE VEHICLE DELTA V: 30 mph

CIRCUMSTANCES

Vehicles 1 and 2 were traveling in the same direction on a four lane city street. V2 stoped to turn left. V1 impacted the rear of V2 at approximately 45 mph without braking. V2 rotated 180 degrees counter clockwise and came to rest in lane of oncoming traffic. The rear end of V2 was severely damaged.

The lap/shoulder belted driver and passenger of V2 received minor injuries. The occupants were treated at a hospital and released. Both occupants lost 10 days of work.

The front seat backs were rotated rearward approximately 30 degr ees.

The front seats in the case vehicle were bucket seats with folding seat backs. The headrests were adjustable with no damage reported.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSIT1 ON: Driver
SEX: Male
AGE: 19
WEIGHT: 200 1 bs.
HEIGHT: 73 in.
RESTRAINT USED: Lap/Shoulder Bel t

INJURIES	AIS	D/i (X)	PROBABLE SOURCE
Laceration, face	1	3	Fl yi ng Gl ass
Strain, neck	1	3	Impac t
Con tusi on Knee	1	1	Steering Wheel
Laceration ,wrist	1	3	Flying glass

SEATING POSIT1 ON: Ri gh t Front Passenger
SEX: Male
AGE: 31
Height: 71 in.
WEIGHT: 2 3 0 lbs.
RESTRAIPJT USED: Lap/Shoulder Eel t

CASE 88-44-113(Cont)

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Contusion, kidney	2	1	Broom stick from back seat
Abrasion, Pelvis	1	1	(Same as above)
Laceration, Face	1	3	Flying Glass
Sprain, ankle	1	7	Unknown

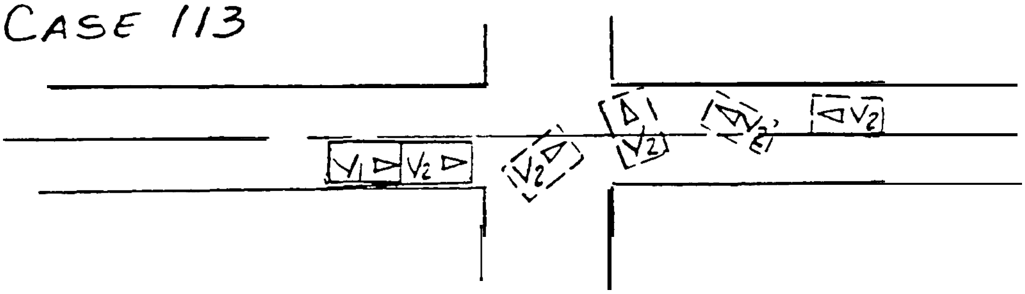
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

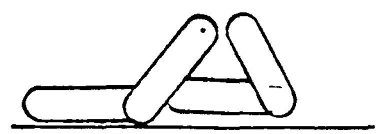
SEAT PERFORMANCE
Driver - Seat back lock failed - rotated approximately 30 degrees. Passenger - Report notes no failure - Photos show about 30 degrees of deflection.

MISC INFORMATION

V1 - 1984 Datsun Maxima - Weight 2880 lbs. - Delta V 26 mph

CASE 113





Seats
Following Impact

CASE 89-45- 12 1

CASE VEHICLE: 1987 FORD TEMPO (V2)
CASE VEHI CLE WEI GHT: 2602 lbs.
CASE VEHICLE DELTA V: 30 mph

CIRCUMSTANCES

Vehicle 3 was stopped, preparing to turn left accross two lanes of traffic on a four lane highway. Vehicle 2 was stopped behind vehicle 3. Vehicle 1 came from behind and struck V2 in the rear. This forced V2 into the rear of V3. The unrestrained driver in the case vehicle, V2, was unrestrained and received minor injuries. He received no treatment. V2 sustained severe rear end damage. The driver's seat back folding locks and seat adjustment tracks failed. The seat back rotated rearward approxmately 40 degrees.

The seats in the case vehicle were bucket seats wtih folding backs, and the headrests were adjustable with no damage reported.

RESTRAINT AND INJURIES

CASE VEHI CLE
SEATING POSIT1 ON: Driver
SEX: Male
AGE: 37
WEIGHT: 1 4 0 lbs.
HEIGHT: 65 in.
RESTRAINT USED : None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Laceration, Face	1	1	Windshield
Contusion, Chest	1	1	Steering Wheel

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury

SEAT PERFORMANCE
Driver - Seat back folding locks and seat track failed.

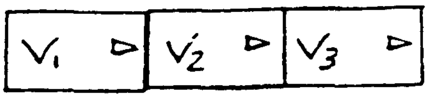
MISC INFORMATION

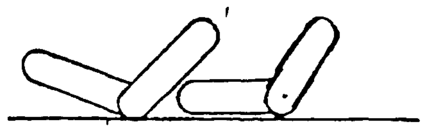
V1 - 1971 Ford Torino Wagon - Weight 3768 lbs. - Delta V 21 mph
v 3 - 1985 Lincoln Mark VII - Weight 4015 - Delta V 11 mph

Note: The case vehicle was involved in a frontal impact following the rear- impact.

CASE 89-45- 12 1 (CONT)

CASE 121





Seats Following Impact

CASE 134

CASE VEHICLE: 1983 Buick Regal (V2)
CASE VEHICLE WEIGHT: 3472 Pounds
CASE VEHICLE DELTA V: 37 mph

CIRCUMSTANCES

Vehicle 2 was stopped at the bottom of a hill at an intersection. Vehicle 1 hit Vehicle 2 in the rear.

During the impact both of V2's front seats deflected (rotated> 54 - 60 degrees rearward. The vehicle sustained severe rear damage.

Neither the driver or the front seat passenger were restrained.

The driver sustained minor injury and the front seat passenger no injuries. The driver was transported to a trauma center and released. It is not known if he lost any days from work.

The front seat of the case vehicle was a split bench seat with adjustable headrest, There was no reported damage to the headrests.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX; Male
AGE: 20
RESTRAINT USED: None

INJURIES	AIS	PROBABLE SOURCE
Contusion, chest wall	1	Steering Wheel

SEAT LOCATION: Right Front
SEX: Male
AGE: 9

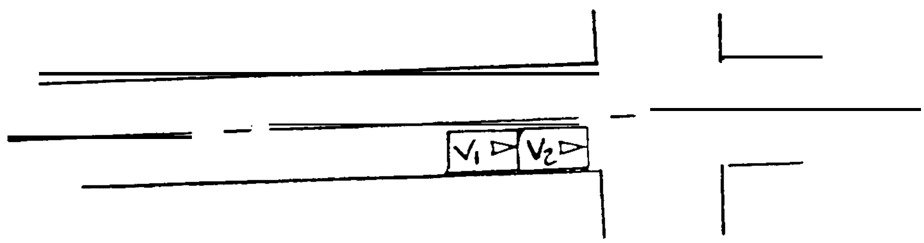
This occupant was unrestrained and received no injury.

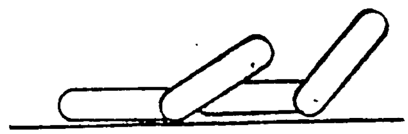
SEAT PERFORMANCE
Both seats coded deformed by occupant impact - approximately 60 degrees.

MISC INFORMATION
V1 - 1988 Ford Thunderbird - Weight 3537 lbs. - Delta V 36 mph

CASE 90-7-134

CASE 134





Seats Following Impact

CASE 89-77-160

CASE VEHICLE: 1977 VW Rabbit (V1)
CSAE VEHICLE WEIGHT: 2015 lbs.
CASE VEHICLE DELTA V: 36 mph

CIRCUMSTANCES

Vehicle V1 had slowed down for a parked vehicle in the curb lane of a six lane road (three each direction> when hit in the rear by v2. V1 and V2 came to rest in the center lane. The driver of the case vehicle, whose seat belt released (button popped out) during the accident received minor injuries. The seat back failed from impact by the occupant (approximately 60 - 70 degrees of rotation> and came to rest on top of the rear seat cushion.

The front seats in the case vehicle were bucket seats with adjustable headrests. No damage was reported on the headrests.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSIT1 ON: Driver
SEX: Female
AGE: 19
HEIGHT: 69 in.
WEIGHT: 155 lbs.
RESTRAINT USED : Lap/Shoulder Belt but released during crash

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Contusion, Forearms	1	1	Left Instr. Panel
Contusion, Head	1	1	Headrest
Concussion, Head	1	1	Headrest

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury

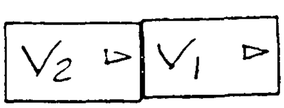
SEAT PERFORMANCE

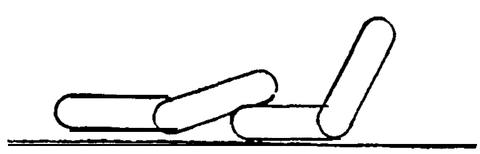
Driver - Seat back broke from driver impact

MISC INFORMATION

v 2 - 1977 Olds Cutlass - Weight 4355 lbs. - Delta V 17 mph

CASE 160





Seats Following Impact

CASE 90-45-232

CASE VEHICLE: 1986 Chevrolet Spectrum (V2)
CASE VEHICLE WEIGHT: 2314 Pounds
CASE VEHICLE DELTA V: 39 mph

CIRCUMSTANCES

Vehicles 1,2,and 3 were traveling on an interstate highway in the first lane. Vehicles 2 and 3 had slowed down for traffic congestion when vehicle 1 struck the rear of vehicle 2 and pushed it into vehicle 3. After initial impact V1 rotated clockwise into vehicle V4's path of travel in the second lane. Vehicle 2 sustained severe rear end damage. There were four occupants in the case vehicle. The two front seat occupants were restrained by lap/shoulder belts and the two rear seat occupants were restrained by lap belts. The driver sustained a AIS 2 head injury, the right front passenger and left rear passenger sustained AIS 1 (minor> injuries., and the right rear passenger no injuries. All occupants were transported to the hospital and released. The driver lost 15 days of work.

The report notes no front seat failure, however the right front seat appears to be rotated rearward approximately 20 degrees past its normal position. The rear seat was pushed forward by intrusion, with the seat back resting against the back of the driver's seat.

The front seats of the case vehicle were bucket seats with folding seat backs and adjustable headrests with no damage reported.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: DRIVER
SEX: Female
AGE: 30
HEIGHT: 63 in.
WEIGHT: 230 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(X)	PROBABLE SOURCE
Contusion, Head, W/Memory Loss	2	1	Steering Wheel
Contusion, Scalp	1	1	Head Restraint
Contusion, Forehead	1	1	Steering Wheel
Contusion, Right Arm	1	1	Steering Wheel
Contusion, Right Wrist	1	1	Steering Wheel
Contusion, Left Leg	1	1	Left Instr. Panel
Strain, Back	1	3	Unknown

CASE 90-45-232(CONT)

SEAT LOCATION: Right Front
SEX: Female
AGE: 29
HEIGHT: 61 ins.
WEIGHT: 200 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Lacerations, Face	1	3	Flying Glass
Abrasions, Face	1	1	Head Restraint
Contusions and Abrasions, Whole Body	1	7	Unknown

SEAT LOCATION: Left Rear Seat
SEX: Male
AGE: 3
RESTRAINT USED: Lap Belt

INJURIES	AIS	D/I(*)	PROBABLE CAUSE
Abrasions and Contusions, Scalp	1	1	Seat, intruding from rear seat
Abrasion, Left Ear	1	1	

SEAT LOCATION: Right Rear
SEX: Female
AGE: 5
RESTRAINT USED: Lap Belt

NO Injuries

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

Note: Since this car was involved in multiple impacts, it would be hard to determine how the driver was forced into the steering wheel.

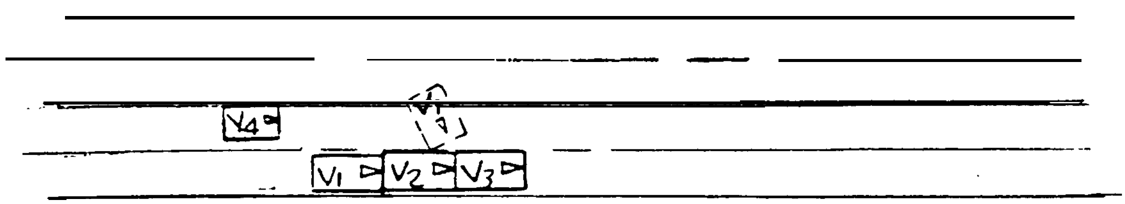
SEAT PERFORMANCE
The accident report notes no seat failures, however the right front seat appears to be rotated approximately 20 degrees beyond its normal position.

CASE 90 -45-232 (CONT)

MI SC INFORMATI ON

V1 - 1978 Chevy Van - Delta V 21 mph - Weight 4209 lbs.
v 3 - 1986 Chevy Van
v4 - 1985 Nissan Pulsar

CASE 232



CASE 262

CASE VEHI CLE: 1987 Honda Civic (V2)
CASE VEHICLE WEIGHT: 1887 lbs.
CASE UEHI CLE DELTA V: 38 mph

CI RCUMSTANCES

Vehicle 2 was stopped in the left lane of a four lane highway preparing to turn left. Vehicle 1 struck V2 from behind. V2 was driven accross both lanes of oncoming traffic, rotating counter clockwise, and coming to rest against a parked car.

The rear of V2 was severe1 y damaged. The driver's seat back was. deflected rearward approximately 38 degrees by the impact force.

The unrestrained driver received a fractured pelvis, was hospital ized seven days, and had not returned to work at the time the report was released.

The seats in the case vehicle were bucket seats with folding seat backs and adjustabl e headrests.. There was no reported damage to the headrests.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSIT1 ON: Driver
SEX: MALE
AGE: 24
HEIGHT: 73 in.
WEIGHT: 188 lbs.

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Fracture, Pelvis	7	7	Unknown
Contusion, Arm, Head	1	7	UnI:nown

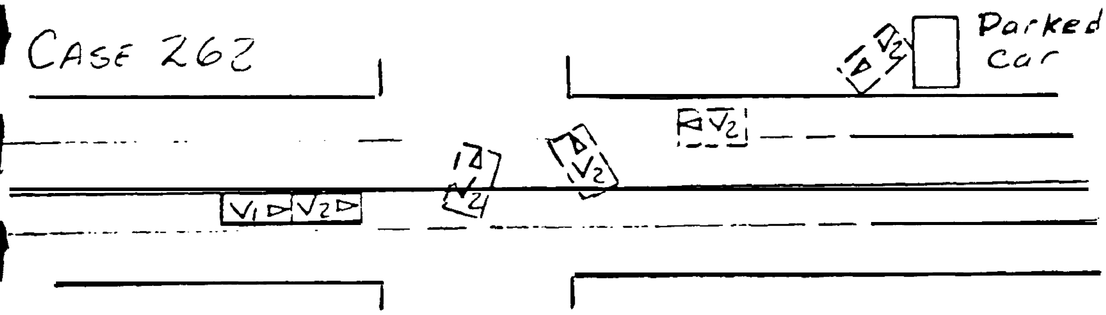
(*) D/I Direct/Indirect Injury - (7) Unknown Source

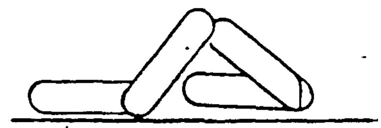
SEAT PERFORMANCE
Driver's seat deformed by passenger compartment intrusion.

MI SC INFORMATI ON

V1 - 1977 01 ds Omega - Weight 3454 lbs. - Delta V 22 mph

CASE 88-45-262(CONT)





Seat Following Impact

APPENDIX D

Thirty-one Rear Impacts

NASS 1988- 1992

SUMMARY - FRONT SEAT OCCUPANT CONTACT OF COMPNENTS FORWARD OF OCCUPANT - ALL REAR IMPACT CASES REVIEWED

0 THERE WERE 34 FRONT SEAT OCCUPANTS IN THE REAR IMPACT CASES REVIEWED THAT CONTACTED COMPONENTS FORWARD OF THE OCCUPANTS, i.e., STEERING WHEEL, WINDSHIELD, SUNVISOR, MIRROR, SEAT BELT, AND INSTRUMENT PANEL

0 30 WERE BELTED AND 4 WERE UNRESTRAINED

0 20 WERE IN VEHICLES INVOLVED IN MULTIPLE IMPACTS, AND 14 WERE INVOLVED IN SINGLE IMPACTS

0 A SUMMARY OF THIS VERY LIMITED SAMPLE IS SHOWN BELOW

	BELTED OCCUPANTS		UNRESTRAINED	
AIS	IMPACTS - MULTIPLE(M) OR SINGLE(S)			
	M	S	M	S
1	7	8	2	2
2	10	3	-	-
3	1	1		

0 THE MAJORITY OF THE AIS 2 AND 3 INJURIES WERE TO OCCUPANTS IN MULTIPLE IMPACTS, IN WHICH THE FORWARD MOTION OF THE OCCUPANT COULD BE INFLUENCED BY THE SECOND (FRONTAL)IMPACT AS WELL AS THE OCCUPANT REBOUNDING FROM THE SEAT FOLLOWING THE REAR IMPACT.

CASE 89-4 l-008

CASE UEHI CLE: 1989 Chry LeBaron Conver tabl e, 2-Door(V2)
CASE UEHI CLE WEI GHT: 2860 lbs.
CASE VEHICLE DELTA V: 15 mph

CIRCUMSTANCES

V1 was traveling on a state road going approximately 45 mph. V2 and V3 were stopped in the left 1 ane. V1 rear ended V2 on right rear side. V2 was pushed into U3. V2 received moderate rear damage.

The case vehicle was being driven with the convertable top down.

The case vehicle was equipped with a driver side air bag. Both front seat occupants were using their lap/shoulder bel ts. The air bag functioned properly although the driver complained of a burn. The bel ted right front passenger received three broken ribs from the shoulder belt and was hospitalized for four days. The right side window shattered during the crash.

The front seats of the case vehicle were bucket seats with folding seat backs and adjustable headrests. There was. no r epor ted damage to the headrests. The driver's seat rotated approximately 60 degrees aft during the crash.

RESTRA I NT AND INJUR I ES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 39
HEIGHT: 71 in.
WEIGHT: 1 9 7 lbs.
RESTRAINT USED: Lap/Shoulder Bel t t Air Bag

INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Strain, Neck	1	1	Seat Bel t
Strain, Back	1	1	Seat Back
Contusion, Thigh	1	1	Steering Wheel
Burn, Thigh	1	3	Air Bag

SEATING POSITION: Right Front Passenger
SEX: Fema 1 e
AGE: 42
HEIGHT: 61 in.
WEIGHT: 135 lbs.
RESTRAINT USED: Lap/Shoulder Belt

CASE 89-41-008(CONT)

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Laceration, Face	1	3	Flying Glass
Laceration, Thigh	1	3	Flying Glass
Lacetion, Leg	1	3	Flying Glass
Fracture, Three Ribs	2	1	Belt Webbing

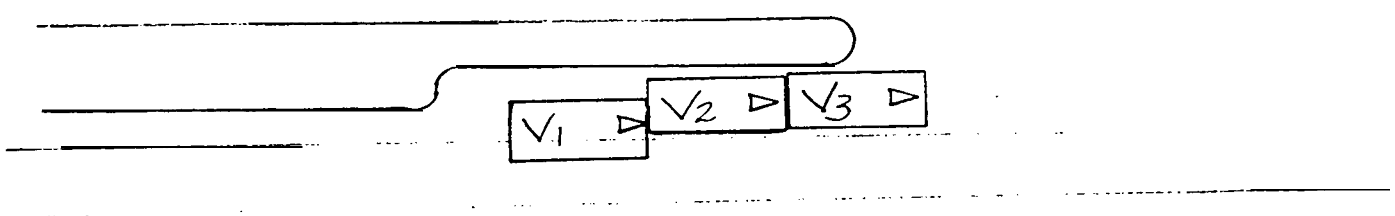
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, and (3) Noncontact Injury

SEAT PERFORMANCE
Driver's Seat - Seat back folding locks failed
Right Front Passenger's seat - No failure

MISC INFORMATION

V1 1982 Chevrolet Station Wagon - 4185 lbs. - Delta V 11 mph
V3 1985 Chevrolet Pickup

CASE 89-41-008



Picture, 10 to 20° Bend in seat

CASE 88-45-009

CASE UEHICLE: 1979 Mercedes 280 CE, 2-Door (V2)
CASE UEHICLE WEIGHT: 3530 lbs.
CASE UEHICLE DELTA V: 20 mph

CIRCUMSTANCES

Vehicle l's brakes failed causing impact the rear of U2, pushing V2 into U3. V2 and U3 were stopped at a traffic signal. V2's front seats were bucket seats with folding seat backs. The front seat headrests were adjustable. There were no reported front seat or headrest failures. The driver of V2 lost five days work as a result of the accident.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 38
HEIGHT: 71 in.
WEIGHT: 165 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Face, Abrasion	1	1	Steering Wheel
Knee, Contusion	1	1	Lt. Instr. Panel
Head, Concussion	2	2	Steering Wheel
Neck, Strain	1	2	Steering Wheel

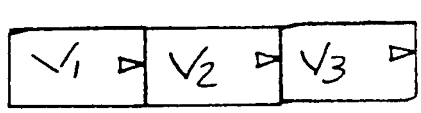
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, and (2) Indirect Contact Injury

SEAT PERFORMANCE
Driver - No failure
Right Front - Unoccupied - No damage

MISC INFORMATION

V1 1974 Pontiac Grand Prix - Weight 4231 lbs. - Delta V 17 mph

CASE 88-45-009



CASE 88-81-0 18

CASE UEHI CLE: 1983 Mercury Capri, 2-Door(V2)
CASE UEHI CLE WE1 GHT: 2775 1 bs.
CASE UEHI CLE DELTA V: 17 mph

CIRCUMSTANCES

Vehicle 1 struck V2 in left rear. The damage to the rear of V2 was moderate1 y severe. V2's front seats were bucket seats with folding seat backs. The driver's seat yielded about 35 degrees and the right front seat about 40 degrees. The integral headrests were not damaged. The driver lost three days work as a result of the accident.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSIT1 ON: Driver
SEX:Femal e
AGE: 39
HEIGHT: 67 in.
WEIGHT: 125 lbs.
RESTRAINT USED: Lap/Shoulder Bel t

INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Head, Contusion	1	7	Unknown
Head, Concussion	2	7	UnKnown
Knee, Contusion	2	1	Lt. Instr. Panel
Leg, Contusion	2	1	Ctr. Instr. Panel

SEATING POSITION: Right Front
SEX: Male
AGE: 39
Height: 71 in.
Weight: 185
Restraint Used: Lap/Shou 1 der Belt
No Injuries

SEATING POSITION: Right Rear
SEX: Femal e
AGE: 39
HEIGHT: 64 in.
WEIGHT: 100 lbs.
RESTRAINT USED: Lap Bel t

CASE 88-81-018(CONT)

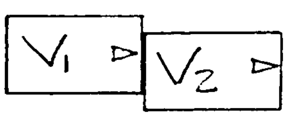
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Laceration	1	3	Flying Glass
Chest, Fracture i(3 Ribs)	2	1	Front Seat Sack
Pelvis, Fracture	3	7	Unknown

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

SEAT PERFORMANCE
Driver and Right Front Passenger Seats - Deformed by occupant from front.
Rear Seat - Deformed by passenger compartment intrusion, and also coded deformed by own inertia.

MI SC INFORMATION
V1 1373 Chevrolet Impala - Weight 4284 lbs. - Delta V 13 mph

CASE 83-81-18



Seats Following Impact

CASE 90-76-0 19

CASE VEHI CLE: 1984 Ford Mustang, 2-Door(V1)
CASE VEHI CLE WEI GHT: 2854 1 bs.
CASE VEHICLE DELTA V: 9 mph

CIRCUMSTANCES

Vehicle 1 was in theinside lane waiting to make a left hand turn. The driver of V2 applied the brakes and skidded into Vl. Vl attempted to accelerate away before the impact. Vl received moderate rear damage. The front seats in Vl were bucket seats with folding seat backs. The headrests were adjustable with no damage. It was reported that both front seat folding locks failed. The driver's seat yielded less than 10 degrees and the right front seat 1 ess than 20 degrees. In an interview the driver reported he received a hairline rib fracture. The driver of V1 lost 10 days work and the front seat passenger 6 days. Both V1 occupants used their lap/shoulder bel ts.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 57
HEIGHT: 72 in.
WEIGHT: 210 lbs.
RESTRAINT USED : Lap/Shou 1 der Bel t

INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Chest, Fracture	1	7	Unknown

SEATING POSITION: Right Front Passenger
SEX: Male
AGE: 3 2
HEIGHT: 69 in.
WEIGHT: 160 lbs.
RESTRAINT USED: Lap/Shoulder Bel t

INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Shou 1 der, Dislocation	2	7	Unknown

SEAT PERFORMANCE
Both front seats coded seat back folding locks failed.

MISC INFORMATION
V2 1977 Mercury Bobcat - Weight, 2472 lbs. - Delta V, 12 mph

CASE 90-76-019

V1 ▷

V2 ▷

CASE 88-46-032

CASE VEHICLE: 1986 Olds Delta 88, 4-Door(V2)
CASE VEHICLE WEIGHT: 3141 lbs.
CASE VEHICLE DELTA V: 24 mph

CIRCUMSTANCES

Vehicle 1, traveling south, struck rear of V2. V2 rotated counterclockwise, crossed the median, momentarily stopping with V2 in the left lane of north-bound traffic facing north. V3, in left north-bound lane struck V2 in rear. V4, traveling in the center lane of north-bound traffic, was struck on left side by V2. V2 contained a split bench front seat with adjustable headrests. It was noted that the seat back folding locks failed. The photos showed no yielding. The headrests were not damaged as was the unoccupied right front seat.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 50
HEIOHT: 72 in.
WEIGHT: 189 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion	2	2	Windshield
Face, Contusion	1	1	Windshield
Abdomen, Contusion	1	1	Seat Belt
Shoulder Laceration	1	7	Unknown
Neck, Strain	1	7	Unknown

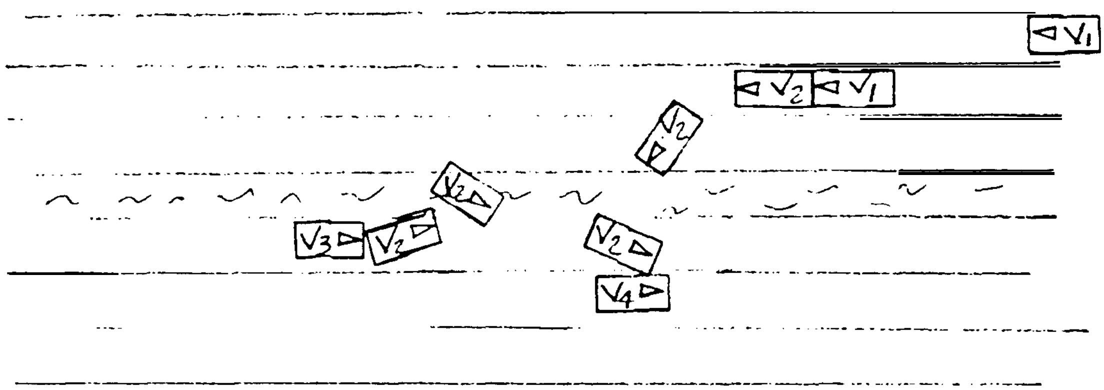
(*) D/I Direct/indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, and (7) Unknown Source

SEAT PERFORMANCE
Driver's - Coded seat back folding locks failed, although photos showed no seat back yield.
Right Front - Unoccupied - No damage

MISC INFORMATION
V1 1978 Ford Thunderbird - Weight 4040 lbs. - Delta V 18 mph
V3 1988 Toyota Camry - Weight 2811 lbs. - Delta V 27 mph
V4 1983 Celica GT - Weight 2496 lbs.

CASE 88-46-032(CONT)

CASE 88-46-32



CASE 88-80-033

CASE UEHI CLE: 1982 VW Jet t a, 2-Door (V2)
CASE VEHI C:LE WE1 GHT: 1832 lbs.
CASE VEHICLE DELTA V: 28 mph

CI RCUMSTANCES

Vehicles Ul, U2, and V3 were traveling in the same direction when traffic stopped. V3 struck V2 in rear pushing it into V1. V3 rolled over possibly striking V1 in the front. The front seats in V2 were bucket seats with a folding seat back. The headrests were adjustable. There was no damage to the seats or headrests.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SEX: Female
AGE: 38
Height: 66 in.
Weight: 130 lbs.
Restraint Used: Lap/Shou 1 der Bel t

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Chest, Burn	3	3	Battery Acid

SEATING POSITION: Right Front
SEX: Male
AGE: 40
RESTRAINT USED: Lap/Shoul der Bel t

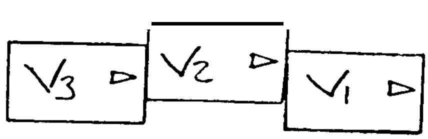
No additional information on this occupant

(*) D/I Direct/Indirect Injury - (3) Noncontact Injury

SEAT PERFORMANCE
Driver and Right Front - No Damage

MISC INFORMATION
V1 1987 Jeep Cherokee - Weight 2774 lbs.
V3 1984 Nissan Pickup - Weight 4328 lbs. (carrying rocks)
Del ta V 11 mph

CASE 88-80-033



CASE 88-50-040

CASE UEHI CLE: 1984 Chevrolet Camero, 2-Door(V2)
CASE VEHICLE WEIGHT: 3054 lbs.
CASE VEHICLE DELTA V: 25 mph

CIRCUMSTANCES

Vehicle 2 had stopped at a stop sign waiting to turn left. V1 impacted rear of U2. The front seats of the case vehicle were bucket seats with folding seat backs. Both front seats were coded seat back folding locks failed. Photos show about a0 degrees of yield on both front seats. Both the driver's and right front seat headrests were damaged. The rear seat was deformed by passenger compartment intrusion.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SEX: Male
AGE: 17
HEIGHT: 73 in.
WEIGHT: 204 lbs.
RESTRAINT USED : Lap/Shou der Belt

INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Head, Laceration	1	3	Flying Glass
Head, Concussion	2	7	UnKnown
Head, Contusion	1	7	Unknown
Face, Laceration	1	3	Flying Glass
Abdomen, Contusion	1	1	Steering Wheel

SEATING POSITION: Right Front
SEX: Male
AGE: 17
HEIGHT: 67 in.
WEIGHT: 140 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Head, Concussion	2	7	Unknown
Face, Unknown Lesion	2	7	Unknown
Face, Laceration	2	7	Unknown
Head, Laceraton	1	7	Unknown
Face, contusion	1	7	Unknown
Ankle, Laceration	1	7	Unknown

CASE 88-50-040(CONT)

SEATING POSITION: Left Rear
SEX: Male
AGE 16
HEIGHT: 72 in.
WEIGHT: 170 lbs.
RESTRAINT USED : Lap Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Neck, Strain	1	3	Impact Force
Head, Laceration	1	7	Unknown

SEATING POSIT1 ON: Right Rear
SEX: Male
AGE: 15
HEIGHt: 74 in.
WEIGHT: 175
RESTRAINT USED: Lap Belt

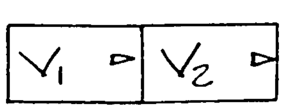
INJURIES	AIS	D/I	PROBABLE SOURCE
Face, Laceration	1	7	Unknown
Face, Contusion	1	7	Unknown
Neck, Strain	1	3	Noncontact
Neck, Laceration	1	7	Unknown
Back, Strain	1	3	Noncontact

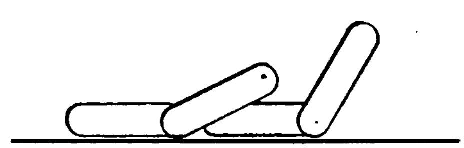
(*) D/I Direct/Indirect Contact Injury - (1) Direct Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

SEAT PERFORMANCE
Driver and right front- Coded seat back folding locks failed
Rear Seat - Deformed by passenger compartment intrusion

MI SC INFORMATION
V1 1983 GMC Sierra Pickup - Weight 2645 lbs. - Delta V 29 mph

CASE 88-50-040





Seats Following Impact

CASE 88-72-040

CASE VEHICLE: 1982 Toyota Corolla, 2-Door (V2)
CASE VEHICLE WEIGHT: 2299 lbs.
CASE VEHICLE DELTA V: 12 mph

CIRCUMSTANCES

Vehicles 1 and 2 were traveling in the same direction when V2 slowed down due to slowed traffic and was rear ended by V1.

V2 suffered light rear damage. It was reported that V2's driver's seat was deformed by the occupant from the front and the seat back folding locks failed. Photos show only about 10 degrees of yield. There was no damage to the adjustable headrests or the unoccupied right front seat. The V2 driver was hospitalized for one day and lost ten days work. It was reported that the driver wore his seat belt loosely.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 42
HEIGHT: 70 in.
WEIGHT: 170 lbs.
RESTRAINT USED: Lap/Shoulder Belt - Worn Loosely

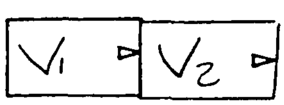
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion	2	2	Windshield
Face, Laceration	1	1	Steering Wheel
Knee, Contusion	1	1	Lt. Instr. Panel
Face, Contusion	1	1	Windshield
Neck, Strain	1	3	Noncontact

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect contact Injury, and (3) Noncontact Injury

SEAT PERFORMANCE
Driver Seat - Seat back foldng locks failed and deformed by impact of occupant from front.
Right Front - Unoccupied - no damage

MISC INFORMATION
V1 1976 Pontiac Firebird - Weight 2299 lbs. Delta V 8 mph

CASE 88-72-40



Seats Following Impact

CASE 45-055

CASE VEHICLE: 1979 Dodge St. Regis, 4-Door (V2)
CASE VEHICLE WEIGHT: 3710 Its.
CASE VEHICLE DELTA V: 8 mph

CIRCUMSTANCES

Vehicle 1 struck V2 in rear as they were approaching intersection. V2's front seat was a bench seat with adjustable headrest. There was no reported damage to the seat or headrest. V2's driver claimed loss of consciousness. No head injury was noted. He spent three days in the hospital and was out of work for over 61 days. This case is hard to explain considering the 8 mph delta V.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 26
HEIGHT: 67 in.
WEIGHT: 165 lbs.
RESTRAINT USED: Lap/Shoulder Belt

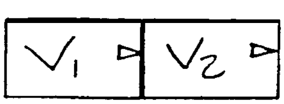
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion	3	7	Unknown
Neck, Strain	1	7	Unknown
Back, Strain	1	7	Unknown

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (7) Unknown Source

SEAT PERFORMANCE
Driver - No Failure

MISC INFORMATION
V1 1987 Ford Escort - Weight 2222 lbs. - Delta V 11 mph

CASE 88-45-055



CASE 90-9-056

CASE VEHICLE: 1988 Volvo 740 GLE, 4-Door(V2)
CASE VEHICLE WEIGHT: 2930 lbs
CASE VEHICLE DELTA V: 17 mph

CIRCUMSTANCES

Vehicles 2 and 3 were stopped at a traffic signal. V1 rear ended V2 and pushed it into V3. The case vehicle received moderate rear damage. The frontal damage of V2 appeared as severe as the rear impact damage. Both case vehicle occupants were using seat belts. The case vehicle contained bucket seats with integral headrests. There was no reported headrest damage. Both front seats rotated aft approximately 30 degrees. The driver received a chest fracture and was hospitalized for four days.

RESTRAINT AND INJURIES

CASE 'JEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 34
HEIGHT: 63 in.
WEIGHT: 134 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Contusion, Face	1	1	Steering Wheel
Contusion, Chest	1	1	Steering Wheel Hub
Contusion, Abdomen	1	1	Seat Belt Webbing
Contusion, Forearm	1	1	Transmission Lever
Contusion, Lt Thigh	1	1	Belt Webbing
Contusion, Rt Thigh	1	1	Belt Webbing
Fracture, Chest	2	1	Steering Wheel

SEATING POSITION: Right Front Passenger
SEX: Male
AGE: 24
HEIGHT: 71 in.
WEIGHT: 235 lbs.
RESTRAINT USED: Lap/Shoulder Belt

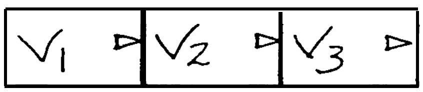
INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Contusion, Lower Limbs	1	1	Rt. Instr. Panel
Strain, Neck	1	1	Headrest

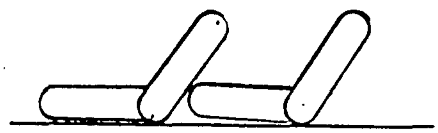
CASE 90-9-056(CONT)

SEAT PERFORMANCE
Driver's Seat - Reclining Lock Failed
Right Front Passenger's - Deformed by impact of occupant

MISC INFORMATION
V1 1986 Honda Accord - Weight 2579 lbs. - Delta V 20 mph
V3 1988 GMC Suburban 2500 - Weight 4816 lbs.,

CASE 90-9-056




Seats Following Impact

CASE 90-80-063

CASE VEHICLE: 1985 Chevrolet Chevette, 2-Door(V2)
CASE VEHICLE WEIGHT: 2090 lbs.
CASE VEHICLE DELTA V: 14 mph

CIRCUMSTANCES

Vehicle 2 had stopped in the roadway for another vehicle which had spun out of control. V1 struck V2 in rear. V2 was pushed into and contacted a guard rail with its left front. Both cars were towed and both occupants of V2, the case vehicle, were transported to the hospital. The case vehicle contained bucket front seats with folding seat backs with no reported damage. The head restraints were integral with the seat with no damage. V2's occupants were using their lap/shoulder belts. The right front passenger was hospitalized for 10 days and lost 14 days of work. The report noted severe rear end damage to V2 but photos show minor damage.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 27
Height: 63 in.
WEIGHT: 106 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I	PROBABLE SOURCE
Neck, Strain	1	7	Unknown

SEATING POSITION: Right Front Passenger
SEX: Male
AGE: 27
HEIGHT: 66 in.
WEIGHT: 150 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, concussion	2	7	Unknown
Neck, Strain	1	7	Unknown

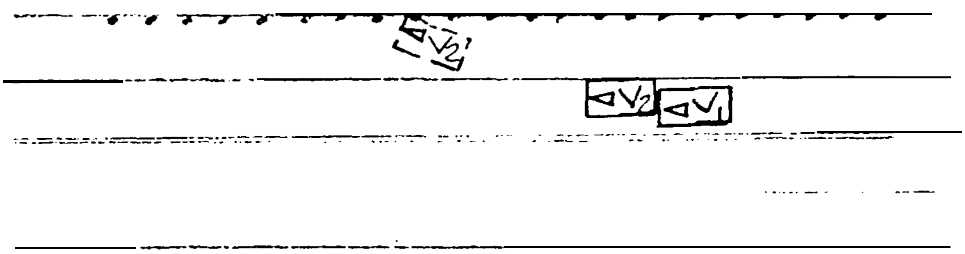
(*) D/I Direct/Indirect Injury - (7) Unknown Source

SEAT PERFORMANCE
No Failures

CASE 90-80-063(CONT)

MISC INFORMATION
V1 1914 Pontiac Grand Am - Weight, 2791 lbs.. - Delta V, 10 mph

CASE 90-80-063



CASE 88-10-066

CASE VEHICLE: 1986 Lincoln Continental, 4-Door (V2)
CASE VEHICLE WEIGHT: 3778 lbs.
CASE VEHICLE DELTA V: 16 mph

CIRCUMSTANCES

Vehicle 1 stopped in first lane of a. four lane road for a disabled vehicle. Vl struck V2 from behind. The V2 driver was transported to the hos.pital. There was moderate damage to the rear of V2. The front seats in V2 were bucket seats. The headrests were adjustable with no damage. The driver's seat was coded deformed by impact of the occupant from the front. A review of the photos showed very little deformation, approximately 15 degrees. The unoccupied right front seat was undamaged. Although it was recorded that the driver rceived a concussion, he only missed one day of work.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 58
HEIGHT: 72 in.
WEIGHT: 210 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion	2	1	Seat Back
Neck, Strain	1	2	Seat Back

(*) D/I Direct/indirect Injury - (1) Direct Contact Injury, and (2) Indirect Contact Injury

SEAT PERFORMANCE
Driver's Seat - Deformed by impact of occupant from front
Right Front -. Unoccupied - No damage

MISC INFORMATION
V1 1978 Ford Thunderbird - Weight 4214 lbs. - Delta V 15 mph

CASE 88-10-066

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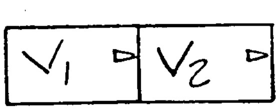
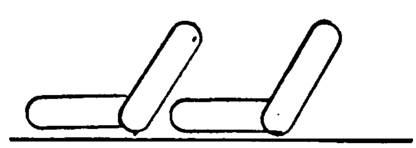




Seats Following Impact

CASE 88-4 l-073

CASE UEHI CLE: 1987 Ford Taurus, 4-Door (V2)
CASE UAHICLE WEIGHT: 2877 1 bs.
CASE UEHI CLE DELTA V: 28 mph

CIRCUMSTANCES

Vehicle 1 was travel ing in the center 1 ane. V2 and V3 were stopped at an intersection. V1 entered V2's lane and struck V2 in rear. V1 rotated 90 degrees counterclockwise where right side of V1 struck rear of U3. V2's front seats were bucket seats with folding seat backs. The headrests were adjustable with no damage reported. The drivers seat was slightly deformed. The right rear passenger died following the accident. The rear sear was deformed by intrusion from the rear. The driver spent four days in the hospital and the right front passenger spent eight days in the hospital .

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SE><: Male
AGE: 52
RESTRAINT USED: Lap/Shou 1 der Bel t

INJURIES	AIS	D/I(X)	PROBABLE SOURCE
Head, Concussion	2	7	Unknown
Back, Strain	1	7	UnI:nown

SEATING POSITION: Right Front
SEX: Male
AGE: 79
RESTRAINT USED : Lap/Shou 1 der Bel t

INJURIES	AIS	D/I(X)	PROBABLE SOURCE
Face, Abrasion	1	1	Rt. Instr. Panel
Face, Contusion	1	1	Rt. Instr. Panel
Chest, Fracture	3	1	Seat Bel t
Head, Contusion	2	7	Unknown
Back, Strain	1	7	Unknown

CASE 4 1-073(CONT)

SEATING POSITION: Left Rear

SEX : Fema 1 e

AGE: 4700

RESTRAINT USED: None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Back, Strain	1	2	Seat Back
Knee, Contusion	1	1	Front Seat Back

SEATING POSITION: Center Rear

SEX: Female

AGE: 76

RESTRAINT USED : None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Pelvis, Fracture	3	1	Seat Back
Face, Laceration	I	7	Unknown
Forearm, Fracture	2	7	Unknown
Head, Concussion	2	7	Unknown
Chest, Fracture	2	7	Unknown
Abdomen, Contusion	1	1	Seat Back

SEATING POSITION: Right Rear

SEX: Female

AGE: 76

HEIGHT. 62 in.

WEIGHT: 138 lbs.

RESTRAINT USED : None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Back, Total Severance	5	I	Seat back
Abdomen, Laceration	4	1	Seat Back
Chest, Fracture	4	1	Seat Back
Head, Lesion Unknown	3	I	Seat Back

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, (3) Noncontact Injury, and (7) Unknown source

SEAT PERFORMANCE

Driver - Deformed slightly by occupant from front.

Right Front - No fai 1 ure

Rear Seat - Deformed by compartment intrusion

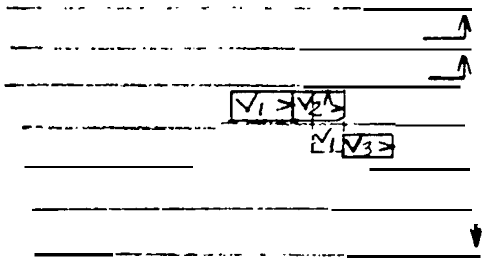
MI sc INFORMATI ON

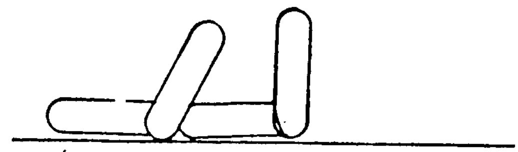
V1 1988 Ford Mustang - Weight 2782 lbs. - Delta v 30 mph

V3 1985 Toyota Pickup

CASE 4 1-073(CONT)

CASE 83-41-73





Seats Following Impact

CASE 90-12-076

CASE UEHI CLE: 1988 Chevrolet Caprice Classic(V1)
CASE VEHICLE WEIGHT: 3654 lbs.
CASE VEHICLE DELTA V: 16 mph

CIRCUMSTANCES

Vehicle 1 was traveling on a wet two lane highway. The vehicle left the road travel ing backwards through a grassy median striking the back of a longitudinal barrier with its right rear corner and then striking its left rear corner with a highway sign post. Both passengers were bel ted. The right front passenger was asleep, woke up, put his feet on the IF to avoid hitting the windshield.

The front seats were bucket seats with folding seat backs. Both seats were deformed rearward by the occupants, the driver's seat approximate1 y 25 degrees, and the right front passenger's seat 30 degrees. The rear of the vehicle was severely damaged in the crash. The headrests were adjustable with no damage.

RESTRAINT AND I NJUR I ES

CASE UEHI CLE
SEATING POSITION: Driver
SEX: Mal e
AGE: 57
HEIGHT: 70 in.
WEIGHT: 160 lbs.
RESTRAINT USED: Lap/Shoul der Eel ts

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Laceration, Face	I	3	Fl yi ng Gl ass
Contusion, Head	2	1	Lt. "B" Pillar
Contusion, Shoulder	2	1	Lt. "B" Pi 1 1 ar
Concussion, Head	2	1	Lt. "B" Pi 11 ar

SEATING POSITION: Right Front Passenger
SEX: Male
AGE: 48
HEIGHT: 69 in.
WEIGHT: 160 lbs.
RESTRAINT USED: Lap/Shoulder Belt

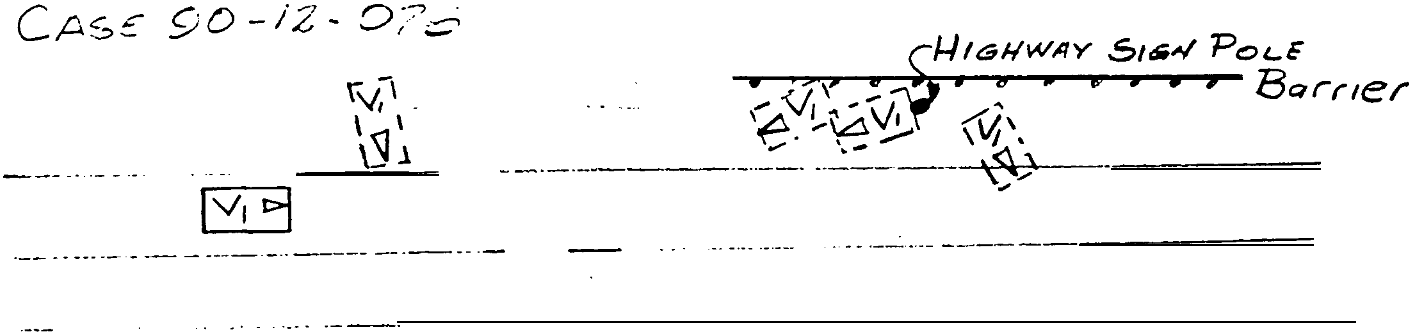
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Strain, back	1	I	Seat Back

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect contact Injury, and (3) noncontact Injury

CASE 90-12-076(CONT)

SEAT PERFORMANCE
Driver's and Right Front Passenger's Seat - Deformed by impact of occupant

CASE 90-12-075



CASE 88-77-079

CASE VEHICLE: 1982 VW Scirocco, 2-Door(V1)
CASE VEHICLE WEIGHT: 2159 lbs.
CASE VEHICLE DELTA V: I7 mph

CIRCUMSTANCES

Vehicle 1 had stopped in traffic when hit in the rear by U2. V1 received moderately light rear damage. The front seats in V1 were bench seats with folding seat backs. The headrests had been removed. There was no seat damage. There was no interior photos taken. V1 received moderately light rear damage.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING FOSITION: Driver
SEX: Male
AGE: 35
HEIGHT: 70 in.
WEIGHT: 195 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Neck, Strain	1	I	Headrest
Head, Concussion	2	7	Unknown

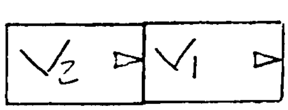
(*) D/I Direct/Inditect Injury - (1) Direct Contact Damage, and (7) Unknown Source

SEAT PERFORMANCE
No seat failure

MISC INFORMATION

V2 1975 Chevrolet Nova - Weight 3416 lbs. - Delta V 12 mph

CASE 88-77-79



CASE 88-10-092

CASE VEHICLE: 1977 Chevrolet Chevette, 2-Door(V2)
CASE VEHICLE WEIGHT: 2019 lbs.
CASE VEHICLE DELTA V: 14 mph

CIRCUMSTANCES

Vehicles 2 and 3 were stopped at a traffic signal. Vi impacted V2 from behind and pushed V2 into V3. The V2 driver was transported to the hospital for a knee injury. V2 received very moderate damage to the rear. Both V2 occupants were using their lap/shoulder belts. The driver of V2 tore his knee ligimates on the dash panel. The seats in V2 were bucket seats. with folding seat backs. The headrests were integral with the seat. No damage was reported to the seats or headrests. The driver of V2 lost two days work. The occupants had bad head aches. and were coded concussions.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 26
HEIGHT: 68 in.
WEIGHT: 150 lbs.
RESTRAINT USED: Lap/Shoulder Belts

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion	1	1	Headrest
Knee, Contusion	1	1	Lt. Instr. Panel
Knee, Laceration	3	1	Lt. Instr. Panel
Back, Strain	1	2	Seat Back

SEATING POSITION: Right Front
SEX: Male
AGE: 38
Height: 72 in.
WEIGHT: 230
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Neck, Strain	1	2	Windshield
Head, Concussion	1	1	Windshield

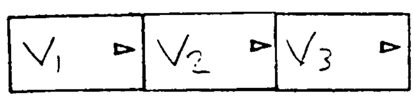
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, and (3) Noncontact Injury

CASE 88-10-092(CONT)

SEAT PERFORMANCE
No seat damage

MISC INFORMATION
V1 1965 Plymouth Barracuda - Weight 2950 lbs. - Delta V 11 mph
V3 1986 Chevrolet Cavalier - Weight 2387 lbs

CASE 88-10-092



CASE 88-45- 103

CASE VEHICLE: 1980 VW Rabbit, 2-Door (V2)
CASE UEHI CLE WE1 GHT: 1810 lbs
CASE VEHICLE DELTA V: 42 mph

CIRCUMSTANCES

Vehicle 2 stopped to turn left. V1 rear ended U2. V2 rotated counterc 1 ockwi se and crossed two 1 anes of traffic into the parking lot which it was attempting to turn into. V2 received severe rear damage. V2 contained bucket front seats with folding seat backs and adjustable headrests. The driver of the case vehicle spent one day in the hospital and lost 5 days work. The right front passenger died following the accident. The right rear passenger was in the hospital over 21 days. The driver's seat appears to have yielded about 30 degrees.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 17
HEIGHT: 70 in.
WEIGHT: 165 lbs.
RESTRAINT USED: Automatic Shoulder Belt

INJURIES	AIS	W I	PROBABLE SOURCE
Head, Laceration	1	7	Unknown
Face, Laceration	1	1	Steering Wheel
Shou 1 der , Contusion	1	7	Unknown

SEATING POSITION: Right Front
SEX: Male
AGE: 44
HEIGHT: 70 in.
WEIGHT: 150 lbs.
RESTRAINT USED: Automatic Shoulder Belt

INJURIES	AIS	D/I (*)	PROBABLE SOURCE
Neck, Fracture	2	3	Noncontac t
Unknown,	7	7	Unknown

Died following accident - Cirtificate of death 1 ists multiple internal injuries.

CASE 45-103(CONT)

SEATING POSITION: Right Rear
SEX: Female
AGE: 18
HEIGHT: 66 in.
WEIGHT: 130 lbs.
RESTRAINT USED: Lap Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Face, Laceration	1	1	Headrest
Chest, Contusion	1	1	Front Seat Back
Chest, Abrasion	1	1	Front Seat Back
Knee, Contusion	1	1	Front Seat Back
Pelvis, Fracture	2	3	Seat Back
Back, Fracture	2	3	Seat Back
Chest, Fracture	1	3	Seat Back

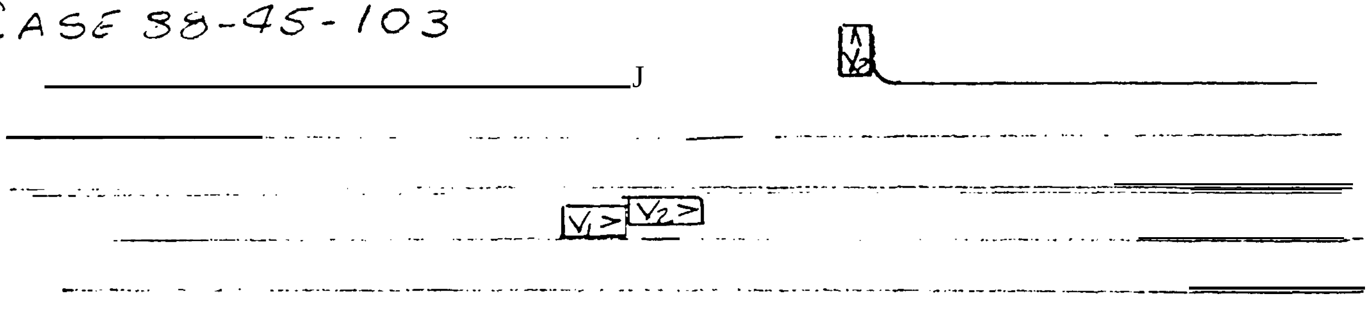
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

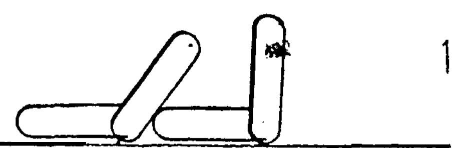
SEAT PERFORMANCE

@river and right front seats coded no failure but driver's seat had yielded approximately 30 degrees.
Rear bench seat deformed by passenger compartment intrusion.

MISC INFORMATION
V1 1986 Ford Mustang - Weight 3140 lbs. - DELTA V 28 mph

CASE 88-45-103





Seats Following Impact

CASE 88-9-110

CASE VEHICLE: 1986 Ford Escort, 4-door(V2)
CASE UEHICLE WEIGHT: 2201 lbs.
CASE VEHICLE DELTA U: 25 mph

CIRCUMSTANCES

Vehicles 2 and 3 had slowed down for a traffic signal. V1 struck V2 from behind pushing it into U3. V2 received severe rear damage. The driver and right front bucket seats were deformed by the impact of the occupants from the front. There was no damage to the front seat adjustable headrests. Both front seats deformed approximately 40 degrees. The driver received a concussion, spent one day in the hospital and lost four days work. The right front passenger also lost four days work.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 25
HEIGHT: 70 in.
WEIGHT: 145 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion	2	1	Steering Wheel
Face, Contusion	1	1	Steering Wheel
Face, Laceration	1	1	Steering Wheel
Forearm, Contusion	1	7	Unknown
Knees, Contusion	1	1	Steering Wheel
Neck, Strain	1	3	Impact Force

SEATING POSITION: Right Front
SEX: Male
AGE: 32
HEIGHT: 75 in.
WEIGHT: 180 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Back, Abrasion	1	1	Own Clothing
Elbow, Contusion	1	7	Unknown

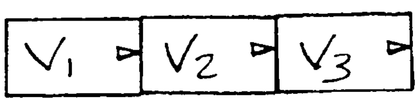
(*) D/I Direct/Indirect Injury (1) Direct Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

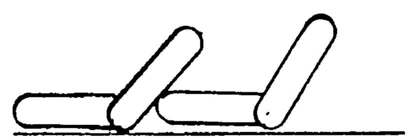
CASE 88-9- 110 (CONT)

SEAT PERFORMANCE
Both front sats deformed by impact of occupants from front

MISC INFORMATION
V1 1987 Chevrolet S-10 Pickup, Weight 2566 lbs., Delta V 23 mph
V3 1980 Mazda 626, Weight 2595 lbs.

CASE 88-9-110





Seats Following Impact

CASE 90-12-129

CASE UEHI CLE: 1985 Buick Skyhawk, 2-Door(V2)
CASE UEHI CLE WE1 GHT: 2400 lbs.
CASE VEHICLE DELTA V: 15 mph

CIRCUMSTANCES

Vehicle 1, traveling on a two lane road, impacted rear of V2 which was stopped, waiting for a left turning vehicle. V2 was pushed into V3 which was also stopped. V1 and V2 were towed. The occupants of V2 and V3 were belted. The occupants of V2 were transported for treatment, V2 received moderate rear damage.

The front seats in V2 were bucket seats with folding backs. The headrests were adjustable with no reported damage.

The driver's seat rotated approximately 45 degrees aft during the accident.

The four year old occupant in the left rear seat received an AIS 3 injury, coded a "burn", from the back of the driver's seat. However, the report noted head trauma, seizures present, suspected brain contusion from front seat back, for this occupant.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SEX : Femal e
AGE: 31
HEIGHT: 65 in.
WEIGHT: 133 lbs.
RESTRAINT USED: Lap/Shoulder Bel t

INJURIES	AIS	D/I(X)	PROBABLE SOURCE
Abrasion, Head	1	1	Steering Wheel Hub
Contusion, Pelvis	1	1	Transmission Lever
Contusion, Thigh	1	1	Steering Wheel
Contusion, Face	1	1	Steering Wheel Hub
Contusion, Head	1	1	Headrest
Contusion, Elbow	1	1	Lt. Side Interior

SEATING POSITION: Left Rear
SEX: Female
AGE: 4
HEIGHT: 44 in.
WEIGHT: 24 lbs.
RESTRAINT USED: Lap Bel t

CASE 90-12-129(CONT)

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Burn, Head	3	1	Front Seat Back
Contusion, Face	1	1	Front Seat Back

SEATING POSITION: Right Rear
SEX: Female
AGE: 5
HEIGHT: 47 in.
WEIGHT: 43 lbs.
RESTRAINT USED: Lap Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Abrasion, Head	1	1	Seat Back
Contusion, Whole Body	1	7	Unknown

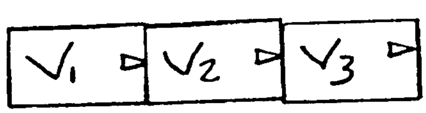
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

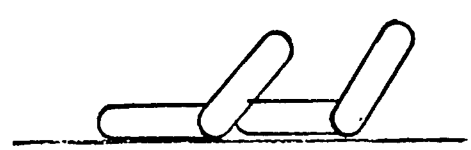
SEAT PERFORMANCE

Driver's Seat - Seat Track/Anchor Failure - Deformed by Occupant
Right Front Passenger - Unoccupied, No Failure
Rear Seat - No Recorded Failure

MISC INFORMATION
V1 - 1974 Plymouth Fury - Weight 4315 lbs. - Delta V 8 mph
V3 - 1987 Chevrolet S-10 Pickup

CASE 90-12-129





Driver's Seat Following Impact

CASE 89-l l-141

CASE VEHICLE: 1989 Ford Probe, 2-Door (V2)
CASE UEHI CLE WE1 GHT: 2715 lbs.
CASE UEHI CLE DELTA V: 25 mph

CIRCUMSTANCES

Vehicles V2 and V3 were stopped in a left turn lane. V1 rear ended V2 pushing it into U3. V1 and V2 were towed from the scene due to damage. V3 was drivable. V2 sustained moderate rear damage. The belt restrained driver of V2 was transported to the hospi tal and released. She lost three days work.

The front seats in the case vehicle were bucket seats. with folding seat backs. The headrests were adjustable with no reported damage. Although there was no reported seat failure, the driver's seat appeared tilted rearward a few degrees further than the right front sear passenger's seat.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSIT1 ON: Driver
SEX: Female
AGE: 30
Height: 66 in.
WEIGHT: 135 lbs.
RESTRAINT USED : Lap/Shou 1 der Bel t

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Concussion, Head	2	1	Steering Wheel
Abrasion, Knee	1	1	Ctr. Instr. Panel
Abrasion, Face	1	1	Steering Wheel
Contusion, Face	1	1	Steering Wheel
Contusion, Elbow	1	1	Tr an s . Lever
Contusion, Knee	1	1	Ctr. Instr. Panel
Contusion, Chest	1	1	Seat Bel t Webbing

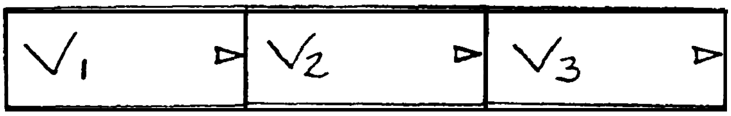
(*) D/I Direct/Inridect Injury - (1) Direct Contact Injury

SEAT PERFORMANCE
No reported seat failure

MI SC INFORMATION
V1 1985 Plymouth Voyager - 2770 lbs. - Delta V 24 mph
V3 1984 Ford Tempo - 2373 1 bs.

CASE 89-11-141 (CONT)

CASE 89-11-141



CASE 90-77-151

CASE VEHICLE: 1989 Ford Taurus, 4-Door (V2)
CASE VEHICLE WEIGHT: 2901 lbs.
CASE VEHICLE DELTA V: 20 mph

CIRCUMSTANCES

Vehicles V1, V2, and V3 were traveling in median lane of a two-way traffic-way with a reverse lane. V3 stopped for traffic and V2 had slowed down. V1 rear ended V2 and pushed V2 into V3 causing minor damage to V3. V1 and V2 were towed. The occupants of V2 were transported to the hospital. V2 received severe underride damage. The occupants of V2 were using their lap/shoulder belts.. The front seat in V2 was a split bench seat with adjustable headrest. There was no front seat or headrest damage reported.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 64
HEIGHT: 63 in.
WEIGHT: 135 lbs.

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Knees, Contusion	1	1	Lt. Instr. Panel
Arms, Contusion	1	7	Unknown
Chest, Contusion	1	1	Steering Wheel
Neck, Strain	1	1	Headrest
Head, Contusion	1	1	Headrest
Head, Concussion	2	1	Headrest

SEATING POSITION: Right Front Passenger
SEX: Female
AGE: 55
HEIGHT: 63 in.
WEIGHT: 150 lbs.

No Reported Injuries

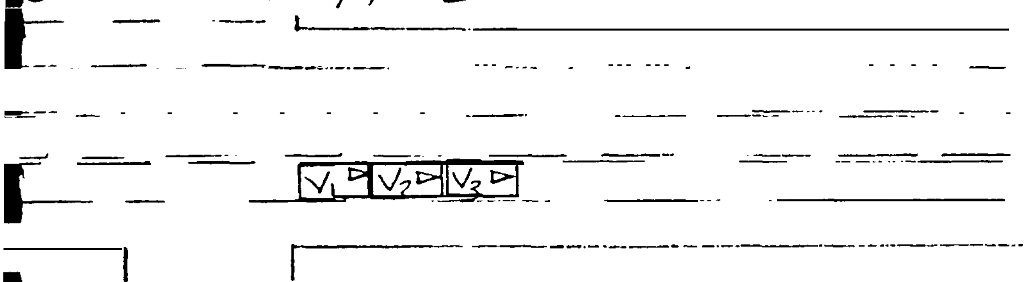
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, and (7) Unknown Source

SEAT PERFORMANCE
No Reported Failures

CASE 80-77-151(CONT)

MISC INFORMATION
V1 1981 Honda Civic - Weight, 1113 lbs. - Delta V, 33 mph
V3 1987 Plymouth Sundance

CASE 90-77-151



CASE 88-11-155

CASE VEHICLE: 1982 Olds Toronado, 2-Door(V2)
CASE VEHICLE WEIGHT: 3700 lbs.
CASE VEHICLE DELTA V: 17 mph

CIRCUMSTANCES

Vehicle 2 stopped in inside lane of a four lane divided highway due to traffic jam. V1 hit V2 in rear. V2 was severely damaged in rear. V2's front seats were split bench with adjustable headrests. The headrests were not damaged. The front seat yielded aft approximately 40 degrees. There was no "Occupant Injury Form" in the file for the right front passenger. However, the case summary indicates neck strain, AIS 1, from impact force.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSIT1 ON: Driver
SEX: Female
AGE: 43
HEIGHT: 64 in.
WEIGHT: 118 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Neck, Strain	1	2	Headrest

SEATING POSITION: Right Front
SEX:mal e
AGE: 14
HEIGHT: 64 in.
WEIGHT: 100 lbs.
RESTRAINT USED: Lap/Shoulder Belt

No Injury Sheet

SEATING POSITION: Left Rear
SEX: Male
AGE: 12
HEIGHT: 60 in.
WEIGHT: 78 lbs.
RESTRAINT USED: None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Neck, Strain	1	3	Impact Force

CASE 88-11-155(CONT)

SEATING POSITION: Right Rear
SEX: Female
AGE: 16
HEIGHT: 65 in.
WEIGHT: 110 lbs.
RESTRAINT USED : None

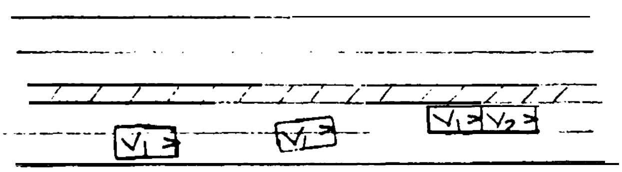
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Laceration	2	3	Hair caught and pulled by impact force
Head, Concussion	1	2	Seat back

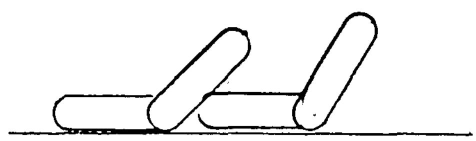
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, aand (3) Noncontact Injury

SEAT PERFORMANCE
Driver and right front seats deformed by impact of occupants from front.
Rear seat - Deformed by compartment intrusion.

MISC INFORMATION
V1 1982 Ford Escort - Weight 2089 lbs. - Delta V 31 mph

CASE 88-11-155





Seats Following Impact

CASE 90-09-158

CASE VEHICLE: 1989 Toyota Camry, 4-Door(V2)
CASE VEHICLE WEIGHT: 3240 lbs.
CASE VEHICLE DELTA V: 9 mph

CIRCUMSTANCES

Vehicles 1, 2, and 3 were proceeding through an intersection, at low speed, same lane, and same direction. An emergency vehicle crossed their path aand V1 came to an abrupt stop. V2 impacted V1 from the rear. V3 then impacted V2 from the rear. There was minor danage to the front and rear of V2. The driver and right front bucket seats were not damaged. The four doors remained operational. There was no headrest damage. The driver used the automatic shoulder belt and the manual lap belt. The driver of V2 claimed loss of consciousness for three minutes. He had no head injury. He lost two days of work.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 26
HEIGHT: 68 in.
WEIGHT: 125 lbs.
RESTRAINT USED: Automatic Shoulder Belt + Mauuual Lap Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Neck, Strain	1	2	Sunvisor
Head, Concussion	2	1	Sunvisor

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, and (3) Noncontact Injury

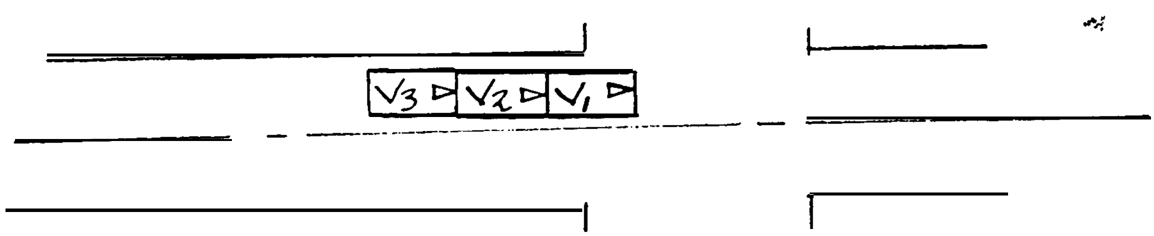
SEAT PERFORMANCE

Driver and unoccupied right front passenger seate - No damage

MISC INFORMATION

V1 1990 Dodge Ram Passenger Van
V3 1984 Audi 4000S - Weight, 2146 lbs. - Delta V, 8 mph

CASE 90-9-158



CASE 88-72-159

CASE VEHICLE: 1982 Dodge Colt, 4-Door (V2)
CASE VEHICLE WEIGHT: 1953 lbs.
CASE VEHICLE DELTA V: 24 mph

CIRCUMSTANCES

Vehicle 1, unoccupied and out of gas, was stopped on roadway. V2 struck V1 and in turn was struck by V3. The front seats in V2 were bucket seats with folding seat backs. Both were undamaged. The seats contained adjustable headrests. V2 received moderately severe damage.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 25
HEIGHT: 71 in
WEIGHT: 150 lbs.
RESTRAINT USED: Lap/Shoulder belt

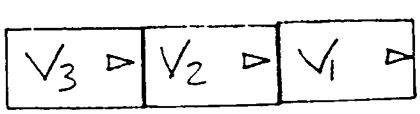
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion	3	7	Unknown
Face, multiple lacerations	1	7	Unknown
Whole Body, Contusions	1	7	Unknown

(*) D/I Direct/Indirect Injury, (1) Direct Contact Injury, (3) Noncontact Injury, (7) Unknown Source

SEAT PERFORMANCE
Driver and unoccupied right front - No failure.

MISC INFORMATION
V1 - 1977 Buick Riviera - Weight 3917 lbs.
V3 - 1986 Pontiac Sunbird - WEIGHT 2347 lbs. - Delta V 19 mph

CASE 88-72-159



CASE 88-10-160

CASE VEHI CLE: 1980 Ford Pinto, 2-Door(V1)
CASE VEHICLE WEIGHT: 2488 1 bs.
CASE VEHICLE DELTA V: 48 mph

CIRCUMSTANCES

Vehicle 1 was traveling in the first lane of an ice covered hi ghway. V1 hit ice on bridge approach and spun a number of times. V2 impacted V1 in rear. V1 burst into flames. V2 was also engulfed in flames from resting against V1. The driver of V1 was transported to a burn facility where he died from cardiac arrest thirteen hours after the accident. The V2 driver was hospitalized for burns. V1 received very severe rear damage. The V1 driver was not in the habit of using the seat bel t. The drivers seat in V1 was a bucket seat with folding back coded no failure. However it was burned by the fire. The driver's head rest was the adjustable type damaged in the accident,

RESTRA I NT AND INJURI ES

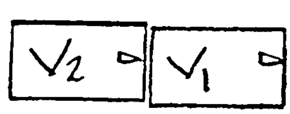
CASE UEHI CLE
SEATING POSITION: Driver
SEX: Male
AGE: 19
HEIGHT: 73 in.
WEIGHT: 200 lbs.
RESTRAINT USED: None

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion	5	7	Unknown
Burn	1	3	Fire
Abdomen, Laceration	2	7	Unknown
Neck, Fracture	2	7	Unknown
Pelvis, Laceration	2	7	Unknown

(*) D/I Direc/Indirect Injury - (1) Direct Contact Injury, (2) Indirect Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

Seat Performance
Reported no failure - Seats so badly burned can't confirm by photos.

MI SC INFORMATI ON
V2 1988 GMC Safari Uan - Weight 3655 1 bs. - Del ta V 34 mph



CASE 90-12-191

CASE UEHI CLE : 1989 Chevrolet Corsica, 4-Door(V2)
CASE VEHICLE WEIGHT: 2595 lbs.
CASE VEHICLE DELTA V: 14 mph

CIRCUMSTANCES

Vehicles 1 and 2 were traveling on a four lane, two way, highway in the second lane. V2 stopped to turn left when hit in rear by V1. The front seats of V2 were bucket seats with adjustable headrests. There was no reported damage to the headrests. Both front seats were deformed approximately 45 degrees by the occupants. V2 received moderate rear damage in the crash.

The case vehicle was equipped with automatic belts. It was reported that the right front passenger's belt "jammed in door".

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SEX : Femal e
AGE: 42
HEIGHT: 59 in.
WEIGHT: 190 lbs.
RESTRAINT USED: Automatic Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Strain, Neck	1	3	Noncontact
Contusion, Leg	2	1	Lt. Instr. Panel

SEATING POSITION: Right Front Passenger
SEX: Female
AGE: 69
HEIGHT: 60 in,
WEIGHT: 140 lbs.
RESTRAINT USED: Automatic Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Strain, Neck	1	3	Noncontact
Contusion, Whole Body	1	1	Seat Back

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, and (3) Noncontact Injury

CASE 90-12-191 (CONT)

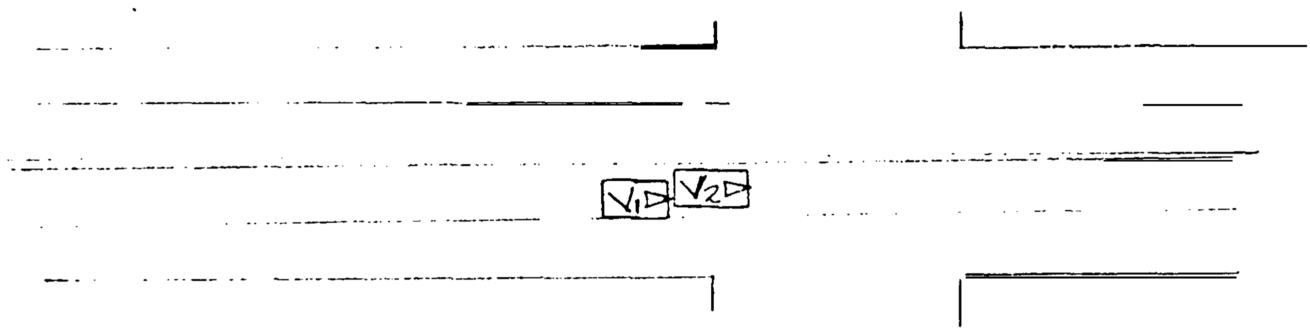
SEAT PERFORMANCE

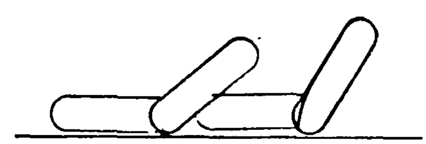
60th front seats. deformed by impact of occupant.

MISC INFORMATION

V1 - 1982 Chevrolet Chevette

CASE 90-12-191





Seats Following Impact

CASE 90-12-192

CASE UEHI CLE: 1988 Ford Escort , 2-Door (V2)
CASE VEHI CLE WEI GHT: 2187 lbs.
CASE VEHICLE DELTA V: 16 mph

CIRCUMSTANCES

Vehicle 1, traveling on a two-way, four lane road rear ended U2, which was stopped in the left turn lane. All occupants were belted. V2 received moderate rear damage. The front seats in V2 were bucket seats with folding backs. The headrests were adjustable with no reported damage. The driver's seat was deformed rearward approximately 45 degrees. The driver lost six days work as a result of the accident.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SEX: Male
AGE: 29
HEIGHT: 75 in.
WEIGHT: 234 lbs.
RESTRAINT USED: Automatic Shoulder Belt + Manual Lap Belt

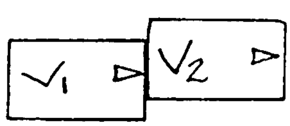
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Laceration, Face	1	1	Steering Wheel
Contusion, Face	1	1	Steering Wheel
Strain, Neck	1	1	Steering Wheel

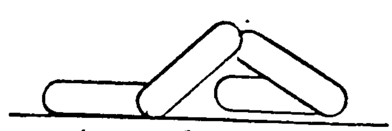
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury

SEAT PERFORMANCE
Driver's Seat - Deformed by occupant impact
Right Front Passenger's Seat - Unoccupied - No Failure

MISC INFORMATION
V1 - 1976 Mercury Bobcat - Weight 2773 lbs. - Delta V 13 mph

CASE 90-12-192





Seats Following Impact

CASE 90-90-71-203

CASE UEHI CLE: 1986 Pontiac Grand Am, 4-Door(V1)
CASE VEHICLE WEIGHT: 2565 1 bs..
CASE VEHICLE DELTA V: 11 mph

CIRCUMSTANCES

Vehicle 1 had stopped on a two-lane undivided highway waiting to turn left into a driveway. V2 struck V1 in rear. Both vehicles were towed. All occupants were transported to the hospital and released. There were four occupants in V1. Both front seat occupants were using their lap/shoulder belts. Both rear seat occupants were using their lap belts. The front seats of V1 were bucket seats with folding seat backs. The headrests were adjustable with no damage. The driver's seat was deformed by impact of occupant and it was. noted that the seat adjusters failed. The right front passenger seat was deformed by impact of the occupant . The front seats had yielded rearward approxitely 25-30 degrees. There was no reported rear seat failure. There was moderate damage to the rear of V1. The 1 ef t rear passenger lost two days work amd the right rear passenger lost seven days, The right rear passenger was sitting turned to the right before the accident.

RESTRAINT AND INJURIES

CASE UEHI CLE
SEATING POSITION: Driver
SEX: Fema 1 e
AGE: 17
HEIGHT: 64 in.
WEIGHT: 165 lbs.
RESTRAINT USED: Lap/Shoulder Bel t

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Contusion	1	1	Headrest

SEATING POSITION: Right Front Passenger
SEX: Femal e
AGE: 17
HEIGHT: 62 in.
WEIGHT: 100 lbs.
RESTRAINT USED: Lap/Shoulder Bel t

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Neck, Strain	1	1	Headrest

CASE 90-71-203(CONT)

SEATING POSITION: Left Rear
SEX: Female
AGE: 16
HEIGHT: 66 in.
WEIGHT: 120 lbs.
RESTRAINT USED: Lap Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
back, Strain	1	1	Seat Back
Back, fracture(**)	2	1	Seat Back

(**) Possible wedging of T-6, T-7, and T-8.

SEATING POSITION: Right Rear
SEX: Femal e
AGE: 17
HEIGHT: 64 in.
WEIGHT: 115 lbs.
RESTRAINT USED: Lap Belt

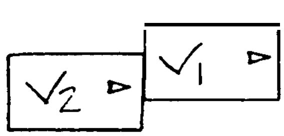
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Concussion (Mild)	1	1	Headrest

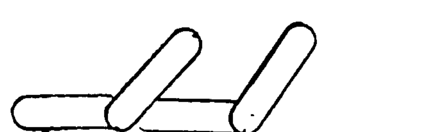
(*) D/I Direct/Indirect Injury - (1) Direct Contact injury

SEAT PERFORMANCE
Driver's seat - Deformed by impact of occupant and seat adjusters failed.
Right front - Deformed by impact of occupant
Rear seat - no failure

MISC INFORMATION
V2 1984 Pontiac J2000 Sunbird

CASE 90-71-203





Seats Following Impact

CASE 88-47-225

CASE UEHI CLE: 1985 Honda Prelude, 2-Door(V1)
CASE UEHI CLE WEI GHT: 2266 1 bs.
CASE UEHICLE DELTA V: 19 mph

CI RCUMSTANCES

Uehicl e 1 was stopped because i t was just previously involved in a frontal impact . V2 struck V1 in rear. Ul's front seat was a bucket seat with folding back. The headrests were adjustable and not damaged. There was no damage to either front seat. The driver of V1 lost two days work as a resul t of the accident.

RESTRAINT AND INJYRI ES

CASE UEHI CLE
SEATING POSITION: Driver
SEX: Fema 1 e
AGE: 38
HEIGHT: 68 in.
WEIGHT: 150 lbs.
RESTRAINT USED: Lap/Shoulder Bel t

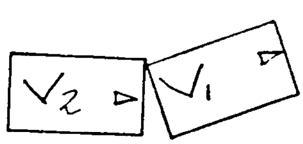
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Head, Laceration	2	1	Lt. "B" Pillar
Shoulder, Contusion	1	1	Lt. "B" Pi 1 lar

(*) D/I Direct/Inditect Injury - (1) Direct Contact Injury, and (2) Indirect Injury

SEAT PERFORMANCE
Neither the driver's or unoccupied right front seats were damaged.

MI SC INFORMATION
V2 1976 Chevrolet Laguna - Weight 4061 lbs. - Delta V 11 mph

CASE 88-47-225



CASE 90-45-241

CASE VEHICLE: 1989 Ford Tempo, 4-Door (V2)
CASE VEHICLE WEIGHT: 2587 lbs.
CASE VEHICLE DELTA V: 16 mph

CIRCUMSTANCES

Vehicle 2 was stopped on a two lane road waiting for traffic to clear when it was rear ended by V1. V2 was pushed into the lane of oncoming traffic when hit in the front left corner by V3. The front seats in V2 were bucket seats with folding seat backs. The headrests were adjustable with no damage reported. The V2 driver's seat was deformed rearward approximately 20 degrees beyond normal. The driver of V2 lost 10 days work as a result of the accident.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 39
HEIGHT: 61 in.
WEIGHT: 220 lbs.
RESTRAINT USED: Automatic Shoulder Belt + Manual Lap Belt

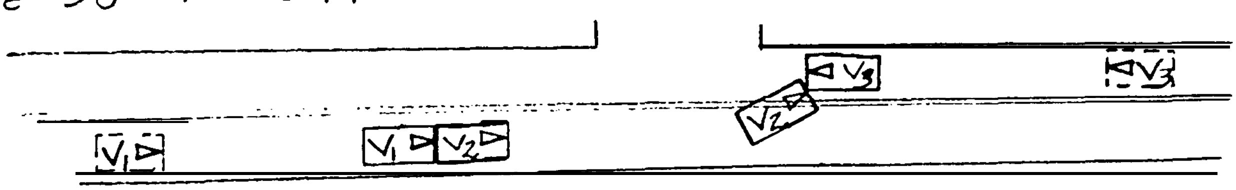
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Fracture, Clavicle	2	1	Belt Webbing
Contusion, Ankle	1	1	Foot Controls

(*) D/I Direct/Indirect INJURY - (1) Direct Contact Injury

SEAT PERFORMANCE
Driver's Seat - Deformed by impact force

MISC INFORMATION
V1 - 1978 Chevrolet Camero - Weight 3537 lbs. - Delta V 12 mph
V3 - 1987 Dodge Ram 150 Truck - Weight 3450 lbs.

CASE 90-45-241



Seats Following Impact

CASE 81-504

CASE UEHI CLE: 1989 Ford Escort, 4-Door (V2)
CASE VEHI CLE WE1 GHT: 2313 lbs.
CASE VEHICLE DELTA V: 18 mph

CIRCUMSTANCES

Vehicle 2 was stopped at a traffic signal in the second lane. V2 was also stopped next to V3 in the center left turn lane. V1 impacted V2 from the rear and then side swipped V3. V2 rotated 188 degrees cl ockwise on impact . All occupants were belted. V1 and V2 were towed from the scene. V3 was driven from the scene. The driver of V2 was transported to the hospital and released.

The case vehicle's front seats were bucket seats with folding seat backs and adjustable headrests. There was no damage reported to the headrests. The driver's seat rotated aft approximately 45 degrees.

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 27
HEIGHT: 71 in.
WEIGHT: 165
RESTRAINT USED: Manual lap belt + Automatic shoulder belt

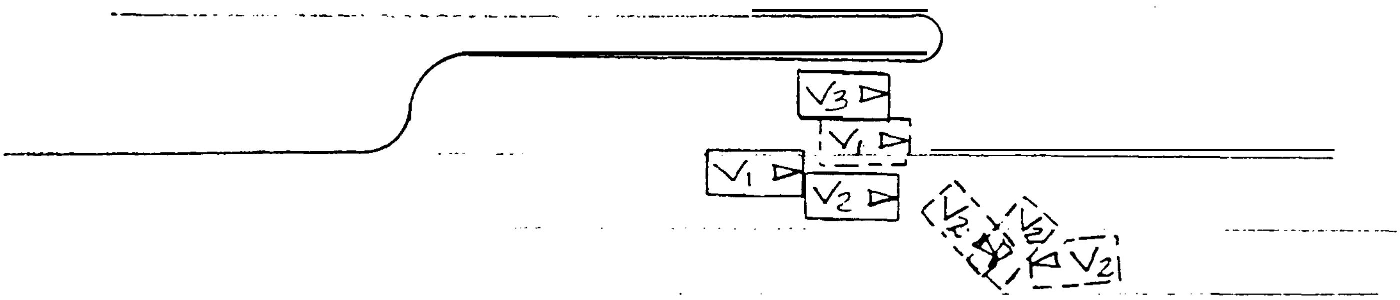
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Strain, neck	1	3	Impact Force
Laceration, Knee	1	7	Unknown

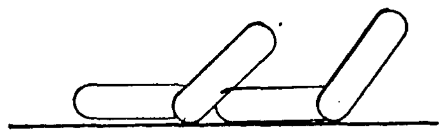
(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury, (3) Noncontact Injury, and (7) Unknown Source

SEAT PERFORMANCE
Driver's Seat - Seat back folding locks failed
Right Front Passenger's Seat - No Failure

MI SC INFORMATION
V1 1998 Chevrolet Storm - Weight 2282 lbs. - Delta V 18 mph
V3 1989 Chevrolet 1500 Pickup

CASE 80-31-504





Seats Following Impact

APPENDIX E

Rear Seat Occupants

in Forty-nine Rear Impact Cases

E

REAR SEAT OCCUPANTS

There were cases in which the case vehicles. contained rear seat occupants. Following is a review of occupant and seat performance in these accidents.

CASE 88-41-073 - 1987 Ford Taurus. - Delta v 28 mph
There were three occupants in the rear seat! all unrestrained? ages 47 to 76. The rear seat was intruded from the rear. The driver's seat was slightly deformed rearward. All three occupants were struck in the back by the back of the rear seat. The left rear passenger received a back strain from the rear seat back and a knee contusion from the front seat back. The center rear passenger received a fractured pelvis. and contusion of the abdomen from the rear seat back plus many injuries of unknown source, many of which cold be from the front seat back. The right rear passenger received catastrophic injury from the rear seat back and died as a result of these injuries.

Since there were many unknown injury sources in this case, it is hard to determine if the rear seat occupants contributed to front seat occupant injury. It is doubtful that the front seat occupants contributed to the rear seat occupants injuries..

CASE 90-47-100 - 1988 Ford Tempo - Delta V 31 mph
There were two occupants in the rear seat. A 34 year old male, restrained, was in the left rear seat. He received injuries from both the back of the front seat and the rear seat back. A 26 year old female, unrestrained, was in the right rear seat. She received minor knee and leg injuries from the back of the front seat. It is doubtful that the rear seat occupants caused any injury to the front seat occupants. The right front seat rotated rearward about 30 degrees.

CASE 90-45-232 - 1986 Chevrolet Spectrum - Delta V 39 mph
There were two occupants in the rear seat. A lap belted three year old was in the left rear seat and a lap belted five year old in the right rear seat. The three year old received minor injuries from the rear seat and the five year old was not injuried. There appears to be no rear seat injuries from the front seat back and it is not apparent that the rear seat occupants caused front seat injury.

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Case 90-71-203 - 1986 Pontiac Grand Am - Delta V 11 mph
There were two lap belted occupants in the rear seat. A sixteen year old in the left rear and a seventeen year old in the right rear. The left rear occupant received a back fracture from the rear seat back. The right rear occupant received a mild concussion from the rear seat headrest. The front seat yielded

rearward approximately 30 degrees. It appears that neither the yielding front seats or the front seat occupants had any influence on rear seat occupant injury, or vice versa.

CASE 88-45-103 - 1980 VW Rabbit - Delta V 42 mph
There was one rear seat occupant , an eighteen year old lap belted female in the right rear seat. The occupant received many minor injuries from the front seat back and a pelvis and back fracture from 'the rear seat back. The right front occupant received a noncontact neck fracture and unknown injuries from an unknown source, and died from multiple internal injuries. It cannot be determined if the rear seat occupant contributed to the front seat occupant..s unknown injuries but it is doubtful if she did.

CASE 90-12-129 - 1985 Buick Skyhawk - Delta V 15 mph
There were two ociupants in the rear seat. A four year old in the left rear and a five year old in the left rear, both lap belted. The left rear occupant received a head burn from the front seat back. The right rear occupant received a minor head abrasion from the rear seat back. The driver's seat yielded approximately 45 degrees and could have contributed to the rear Occupant's injury. There was no right front occupant. The left rear occupant did not contribute to the driver's injuries.

CASE 88-50-040 - 1984 Chevrolet Camero - Delta V 25 mph
There were two occupants in the rear seat, both lap belted. The sixteen year old in the left rear seat received a head laceration from unknown source! possibly the front seat back. The fifteen year old in the right rear received minor face and neck injuries of unknown source, possibly the front seat back . Both front seats yielded about 60 degrees possibly contributing to the rear seat occupants injuries. The driver and-right front passenger received injuries of unknown source. Therefore, it is hard to determine if the rear seat or rear seat occupants contributed to their injuries.

CASE 81-81-018 - 1983 Mercury Capri - Delta V 17 mph
A 39 year old lap belted female was in the right rear seat. She received an AIS 2 rib fracture from the front seat back. The right front seat yielded about 48 degrees. The right front occupant received no injuries.

APPENDIX F

Six Frontal Impacts

NASS 1990

ACCIDENT CASE REVIEW

SIX FRONTAL IMPACTS - 1990 NASS

WITH EMPHASIS ON SEAT PERFORMANCE

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CASE 90-5-005

CASE VEHICLE: 1983 PLYMOUTH RELIANT (V1)
CASE VEHICLE WEIGHT: 2533 lbs.
CASE VEHICLE DELTA V: 15 mph

CIRCUMSTANCES

Vehicle 1 was traveling south on a two lane snow covered road. The driver lost control, departed from the road, and hit a utility pole. The driver was restrained by a lap/shoulder belt. The right front and middle rear passengers were unrestrained. The vehicle contained a split bench seat with adjustable headrests in the front and a bench seat in the rear. The driver received an AIS 3 injury and was in the hospital three days and lost ten days of work, The right front pasenger received AIS 1 injuries and lost one day of work. The rear seat occupant was unijured. It was reported that the seat tracks/anchors failed. The photos show no obvious damage. The right front of the vehicle contacted pole and sustained about 20 inches of crush.

RESTRAINT AND INJURIES;

CASE VEHICLE
SEATING POSITION: Driver
SEX: Female
AGE: 17
HEIGHT: 65 in.
WEIGHT: 130 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	SOURCE
Face, Laceration	2	1	Steering Wheel
Chest, Abrasion	1	2	Seat Belt
Head, Concussion	2	1	Steering Wheel
Face? Fracture	1	1	Steering Wheel
Chest Fracture	3	1	Steering Wheel

SEATING POSITION: Right Front Passenger
SEX: Female
AGE: 16
HEIGHT: 63 in.
WEIGHT: 130 lbs.
RESTRAINT USED: None

INJURIES	AIS	D/I(*)	SOURCE
Face, Abrasion	1	1	Windshield
Face, Laceration	1	1	Windshield
Knee, Contusion	1	1	Rt. Instr. Panel

CASE 90-5-005(Cont)

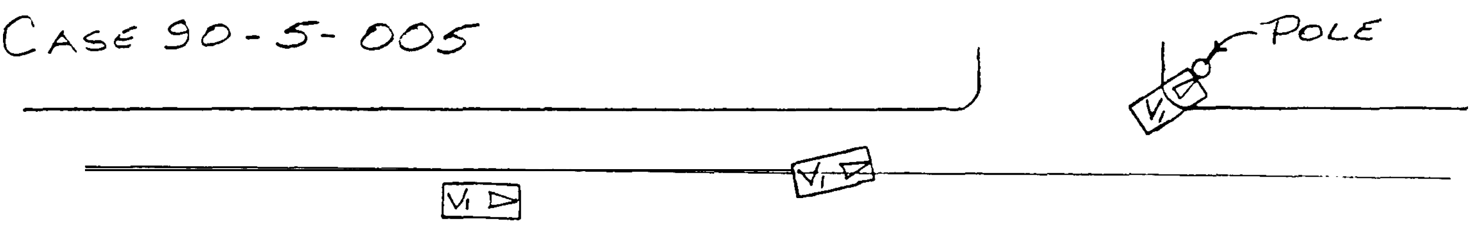
SEATING POSITION: Middle Rear
SEX: Female
AGE: 16
HEIGHT: 63 in.
WEIGHT: 140 lbs.
RESTRAINT USED: None

Injuries - None

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury - (2) Indirect Contact Injury

SEAT PERFORMANCE
Driver's seat coded seat tracks/anchors failed. Photos show no obvious damage.
Right front passenger seat - No Failure
Rear seat - No Failure

CASE 90-5-005



CASE 90-44-011

CASE VEHICLE: 1080 Honda Accord
CASE VEHICLE WEIGHT: 2229 lbs
CASE VEHI CLE DELTA V : 28 mph

CIRCUMSTANCES

Vehicle 1 was travelino on a winding road. The driver was distracted and ran off road on right. V1 went through fence and hit an apple tree. Both occupants were hospitalized. Both the driver and **right** front passenger were unrestrained. The front seats were bucket seats with folding backs. The headrests were adjustable. The driver was horpi tal ized four days and the right front passenger two days , The dr iver s sea t was coded deformed by the 0ccupant fron the front . However, the photos show no deformation. The vehicle contacted the tree with the left front and sustained about 26 inches of crush.

INJURIES AND RESTRAINT

SEATING POSITION: Dr i ver
SEX: Fema 1 e
AGE: 16
HEIGHT: 65 in.
WEIGHT: 118 1 bs.
RESTRAINT USED: None

INJURIES	AIS	D/I(*)	SOURCE
Ankle, Fracture	2	1	Floor Pan
Arm, Fracture	3	1	Steering Wheel
Shoulder, Fracture	2	1	Steerinq Wheel
Chest, Contusion	2	1	Steering Wheel
Face, Laceration	1	3	Flying Glass
Face, Laceration	1	7	Unknown
Face, Abrasion	1	1	Steering Wheel
Lower Limbs, Contusion	1	1	Left Side
Ankle, Avulsion	1	1	Floor Pan

SEATING POSITION: Right Front Passenger
SEX: Female
AGE: 15
HEIGHT: 63 in.
WEIGHT: 185 1 bs.
RESTRAINT USED: None

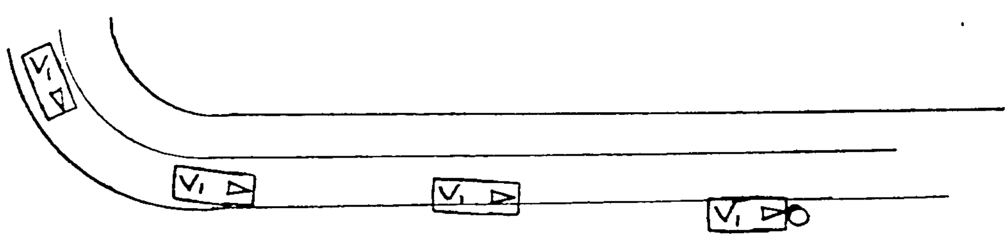
CASE 90-44-011(Cont)

INJURIES	AIS	D/I(*)	SOURCE
Face, Fracture	2	1	Rt. Instr. Panel
Face, Laceration	2	1	" " "
Face, Contusion	1	1	" " "
Head, Concussion	1	1	" " "
Elbow, COntusion	1	7	Unknown

(*) D/I Direct?indirect Injury - (1) Direct Contact Injury - (3) Noncontact Injury - (7) Injury Unknown

SEAT PERFORMANCE
Driver's seat coded deformed by occupant from front. Photos show no obvious deformation.
Right front seat, no failure.

CASE 90-44-011



CASE 90-71-016

CASE VEHICLE: 1982 Dodge Aries (V2)
CASE VEHICLE WEIGHT: 2327 lbs.
CASE VEHICLE DELTA V: 25 mph

CIRCUMSTANCES

Vehicle 1 was northbound on a 2-lane, undivided road. V2 was southbound on the same road. V1 struck V2 headon. V1 rotated 180 degrees counterclockwise. V2 rotated slightly counterclockwise and came to rest on the west shoulder, facing south. The front seat was a bench seat with folding back. The headrests were adjustable. The report noted that the seat tracks/anchors failed although the photos showed no failure. The driver used his lap/shoulder belt. The frontal crush varied from 20 inches on the left to seven inches on the right. The driver spent one day in the hospital,

RESTRAINT AND INJURIES

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 62
HEIGHT: 70 in.
WEIGHT: 170 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	SOURCE
Face, Abrasion	1	1	Steering Wheel
Face, Contusion	1	1	Steering Wheel
Shoulder, Laceration	1	1	Seat Belt
Face, Avulsion	1	1	Steering Wheel
Knee, Abrasion	1	1	Lt. Instr. Panel
Knee, Contusion	1	1	" " "
Knee, Contusion	1	1	Ctr Instr Panel
Face, Laceration	1	1	Steering Wheel
Leg, Fracture	2	1	Steering Wheel
Chest, Contusion	3	1	Steering Wheel
Wrist, Contusion	1	1	Lt. Instr. Panel

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury

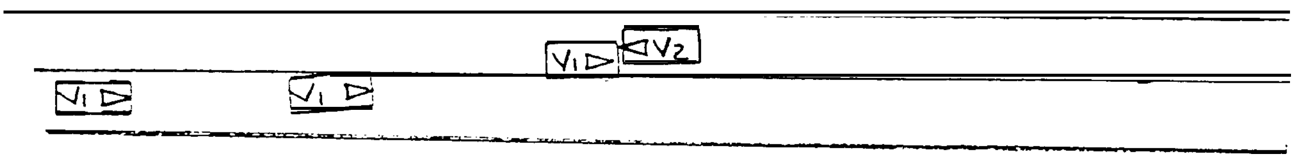
SEAT PERFORMANCE
Seat tracks/Anchors failed although not obvious from photos.

CASE 90-71-016(Cont)

MISC INFORMATION

V 1 - 1982 Plymouth Reliant - Weight, 2327 lbs. - Delta V 26 mph

CASE 90-71-016



CASE 90-02-099

CASE VEHICLE: 1989 Mitsubishi Mirage (V1)
CASE VEHICLE WEIGHT: 2271 lbs.
CASE VEHICLE DELTA V: 24 mph

CIRCUMSTANCES

Vehicle 1 left roadway and struck a tree. The vehicle contained a bucket seat with a folding back. The headrest was adjustable. The right front seat was coded deformed by the occupant. The photos show very little deformation. Although the right front passenger's injury was coded an AIS 1, he died of a stomach hemmorage, coded (96) Fatal - Ruled Disease. The left front of the vehicle sustained 21 inches of crush.

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 30
HEIGHT: 71 in.
WEIGHT: 210 lbs.
RESTRAINT USED: Automatic Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Chest, Contusion	1	1	Stering Wheel
Chest, Abrasion	1	1	" "
Wrist, Abrasion	1	1	Lt. Instr. Panel
Neck, "	1	1	Seat Belt
Chest, Fracture	1	1	Steering Wheel
Chest, Contusion	3	1	" "

SEATING POSITION: Right Front
SEX: Male
AGE: 40
HEIGHT: 64 in.
WEIGHT: 180 lbs.
RESTRAINT USED: Automatic Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Face, Laceration	1	1	Flying Glass

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury

SEAT PERFORMANCE
Driver, No failure - Right front, deformed by occupant

CASE 90-02-099

CASE 90-76-127

CAESE VEHICLE: 1983 Chrysler LeBaron (V2)
CASE VEHICLE WEIGHT: 2801 lbs.
CASE VEHICLE DELTA V: 16 mph

CIRCUMSTANCES

The accident occurred on an icy 2-lane road covered with cinders. V1 was southbound, V2 and V3 both northbound. V1 and V2 impacted left corner to left corner. V3 then impacted V1 front to right side. The case vehicle, V2, contained a bench seat with separate back cushions. and an adjustable headrest. The "Interior" form in the report coded the seat no failure while the "Occupant Assessment " form coded the seat "tracks/anchors" failed. The photos show no observed seat failure. The driver was. using his lap/shoulder belt. The frontal crush on V2 varied from 27 inches on the left to no crush on the right side.

Vehicle 3's seat was also coded tracks/anchors failed. The seat was a split bench with separate back cushions. Both elderly occupants were unrestrained and died in the accident. Again, the photos shown no seat damage. V3 sustained about 20 inches of crush across the front of the car.i

CASE VEHICLE
SEATING POSITION: Driver
SEX : Female
AGE: 55
RESTRAINT USED : Lap/Shoulder Belt

INJURIES	AIS	D/I(%)	PROBABLE SOURCE
Head, Laceration	1	1	Lt. "A" Pillar
Face, Contusion	1	7	Unknown
Face , Laceration	1	7	"
Chest, Contusion	1	1	Steering Wheel
Wrist, Laceration	1	i	Unknown
Head) Fracture	2	1	Lt. "A" Pillar
Head, Concussion	4	1	" " "
Chest, COntusion	3	1	Steering Wheel
Chest, Fracture	3	1	" "
Ankle, Fracture	3	7	Unknown

VEHICLE 3
SEATING POSITION: Driver
SEX : Male
AGE: 84
HEIGHT: 74 in.
WEIGHT: 195 lbs.
RESTRAINT USED : None

CASE 90-76-127(Cont)

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Knee, Abrasion	1	1	Lt. Instr. Panel
Forearm, Abrasion	1	1	Unknown
Chest, Crush	6	1	Steering Wheel

SEATING POSITION: Right Front
SEX: Female
AGE: 81
HEIGHT: 64 in.
WEIGHT: 125 lbs.
RESTRAINT USED: None

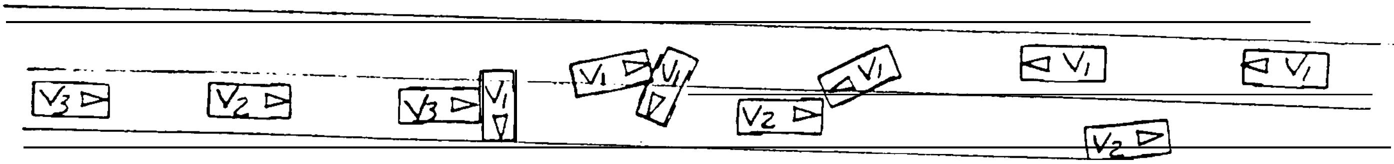
INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Arm, Abrasion	1	1	Rt. Instr Panel
Knee, "	1	1	" " "
Neck, Unknown	7	7	Unknown
Face, Abrasion	1	7	"
Foot, Unknown	7	7	"

(*) D/I Direct/indirect Injury - (1) Direct Contact Injury - (7) Unknown Source

SEAT PERFORMANCE
V2 - Tracks/Anchors Failed
V3 - Tracks/Anchors Failed

MISC INFORMATION
V1 1986 Ford Taurus - Weight 2849 lbs. - Delta V 15 mph
V3 1983 Chevrolet Citation - Weight 2566 lbs. - Delta V 19 mph

CASE 90-76-127



CASE 90-44-129

CASE VEHICLE: 1985 Cadillac Fleetwood (V2)
CASE VEHICLE WEIGHT: 4029 lbs.
CASE VEHICLE DELTA V: 21 mph

CIRCUMSTANCES

Vehicle 1 was traveling on a 2-lane road. V2 was traveling in the opposite direction. V2 began to drift across the center line and struck V1 head on. The frontal crush varied from 47 inches on the left to none on the right. V2 contained a split bench seat with separate back cushions and an adjustable head rest. The driver received an AIS 2 wrist injury and spent one dayin the hospital. The right front. passenger received an AIS 2 ankle fracture and spent six days in the hospital. The right seat moved forward during the impact. The photos show very little forward movement of the seat.

CASE VEHICLE
SEATING POSITION: Driver
SEX: Male
AGE: 69
HEIGHT: 69 in.
WEIGHT: 136 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Wrist, Abrasion	2	7	Unknown
Face, Laceration	1	7	"
Head, Concussion	1	7	"

SAETING POSITION: Eight Front
SEX: Female
AGE: 67
HEIGHT: 59 in.
WEIGHT: 170 lbs.
RESTRAINT USED: Lap/Shoulder Belt

INJURIES	AIS	D/I(*)	PROBABLE SOURCE
Ankle, Fracture	3	7	Unknown
Chest, COntusion	2	1	Seat Belt
Wrist, Avulsion	2	7	Unknown

(*) D/I Direct/Indirect Injury - (1) Direct Contact Injury - (7) Unknown Source

SEAT PERFORMANCE
Drivers seatno failure - Right front seat moved forward due to impact

CASE 90-44-129(Cont)

MISC INFORMATION
V1 1986 Pontiac Grand Am - Weight 2565 lbs. - Delta V 32 mph

CASE 90-44-129